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MHS-623: Climate Change: Mitigation and Policies

1. Mitigation and adaptation relationships:

Mitigation and adaptation are the two types of policy responses to climate change, which have some common elements, they may be complementary, substitutable, independent or competitive in dealing with climate change, and also have very different characteristics and timescales. Both adaptation and mitigation make demands on the capacity of societies, which are intimately connected to social and economic development.

The responses to climate change depend on exposure to climate risk, society's natural and manmade capital assets, human capital and institutions as well as income. Together these will define a society's adaptive and mitigative capacities. Irrespective of the scale of mitigation measures, adaptation measures are required due to the inertia in the climate system.

If countries delay mitigation measures, this has important ramifications for global crop production. The interaction of mitigation with adaptation has been modeled which has further interactions among land-use change, terrestrial carbon emissions, and related factors, which is critical in analyzing interactions between mitigation and adaptation as shown in Fig.1. It reflects not only economic impacts, but also longer-term impacts on natural systems, which in turn help to estimate potential damage, or impacts to be avoided.

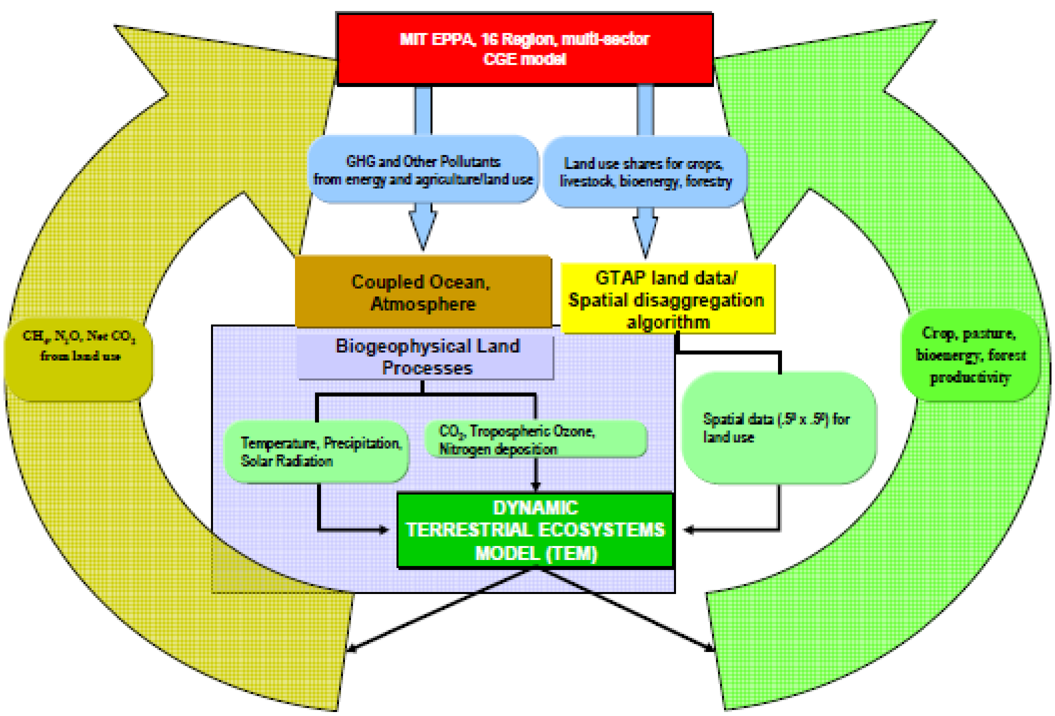

FIGURE 1. Interaction of mitigation and adaptation through land/biofuels.

1.1. Indigenous knowledge on mitigation and adaptation in Africa

African communities and farmers have always coped with changing environments. They have the knowledge and practices to cope with adverse environments and shocks. The enhancement of indigenous capacity is a key to the Empowerment of local communities and their effective participation in the development process. People are better able to adopt new ideas when these can be seen in the context of existing practices.

Local farmers in several parts of Africa have been known to conserve carbon in soils through the use of zero-tilling practices in cultivation, mulching, and other soil-management techniques. Natural mulches moderate soil temperatures and extremes, suppress diseases and harmful pests, and conserve soil moisture. The widespread use of indigenous plant materials, such as agrochemicals to combat pests that normally attack food crops, has also been reported among small-scale farmers. It is likely that climate change will alter the ecology of disease vectors, and such indigenous practices of pest management would be useful adaptation strategies. Other indigenous strategies that are adopted by local farmers include: controlled bush clearing; using tall grasses such as *Andropogon gayanus* for fixing soil surface nutrients washed away by runoff; erosion-control bunding to reduce significantly the effects of runoff; restoring lands by using green manure; constructing stone dykes; managing low-lying lands and protecting river banks.

Adaptation strategies that are applied by pastoralists during the period of drought include the use of emergency fodder, culling of weak livestock for food, and multi-species composition of herds to survive climate extremes. During drought periods, pastoralists and agro-pastoralists change from cattle to sheep and goat husbandry, as the feed requirements of the latter are lower. The nomadic mobility of pastoralists reduces the pressure on low-capacity grazing areas through their cyclic movements from the dry northern areas to the wetter southern areas of the Sahel.

African women are particularly known to possess indigenous knowledge which helps to maintain household food security, particularly in times of drought and famine. They often rely on indigenous plants that are more tolerant to droughts and pests, providing a reserve for extended periods of economic hardship.

2. Sustainable development (SD):

For many in Africa mitigation is not an option but a necessity. The poor usually have a very low adaptive capacity due to their limited access to information, technology and other capital assets which make them highly vulnerable to climate change. An important way of adaptation is sustainable development.

The Bruntland Commission described sustainable development as *“development that meets the needs of the present without compromising the ability of future generations to meet their own needs”*. Sustainable development represents a balance between the goals of environmental protection and human economic development and between the present and future needs. It implies equity in meeting the needs of people and integration of sectoral actions across space and time.

2.1. Sustainable development (SD) & vulnerability in climate change.

Sustainability is closely related to resilience and vulnerability. Sustainable development can reduce vulnerability in climate change by encouraging adaptation, enhancing adaptive capacity and increasing resilience. On the other hand, it is very likely that climate change can slow the pace of progress toward sustainable development either directly through increased exposure to adverse impact or indirectly

through erosion of the capacity to adapt. At present, few plans for promoting sustainability have explicitly included either adapting to climate-change impacts, or promoting adaptive capacity.

Efforts to cope with the impacts of climate change and attempts to promote sustainable development share common goals and determinants like: access to resources (including information and technology), equity in the distribution of resources, stocks of human and social capital, access to risk sharing mechanisms and abilities of decision-support mechanisms to cope with uncertainty. Nonetheless, some developmental activities exacerbate climate-related vulnerabilities.

It is likely that global mitigation efforts designed to cap effective greenhouse gas concentrations at, for example, 550 ppm would benefit developing countries significantly through the middle of this century, regardless of whether the climate sensitivity turns out to be high or low, and especially when combined with enhanced adaptation. Developed countries would also likely to see significant benefits from an adaptation-mitigation intervention portfolio, especially for high climate sensitivities and in sectors and regions that are already showing signs of being vulnerable. By 2100, climate change will likely to produce significant vulnerabilities across the globe even if aggressive mitigation were implemented in combination with significantly enhanced adaptive capacity.

2.2. Sustainable development (SD) and climate change mitigation in developing countries:

The interconnectedness of climate change, sustainable development, and equity poses serious challenges for developing countries but it also presents opportunities. Developing country emissions comprised more than half of global emissions in 2010, and grew during the preceding decade by an amount that accounted for the total global emissions rise. In the absence of concerted mitigation actions, the emissions will increase further. The increase in emissions is due to the fast economic growth and so coincided with a number of positive developments over the past decade like, the overall poverty rate has declined, maternal and child mortality have fallen, the prevalence of several preventable diseases has decreased, and access to safe drinking water and sanitation has expanded, while the Human Development Index (HDI) across nations has risen and its convergence has become more pronounced. Though some gains are there still progress is needed in many other ways throughout the developing world. Many people remain in multi-dimensional poverty, energy insecurity is still widespread, inequality of income and access to social services is persistently high, and the environmental resource base on which humans rely is deteriorating in multiple ways. Added to this unavoidable climate change is amplifying the challenges of development. So now the challenge to the developing world is to progress in a sustainable manner without reproducing the fossil fuel economy like that of the developed world. As such alternative development pathways like innovation in low-carbon technologies and modestly curbed emissions available, the developing world has to pursue in these lines.

2.3. Sustainable development indicators (SDI):

Though there is currently no satisfactory empirical indicator of sustainability available, pressure-state-response (PSR) and capital accounting-based (CAB) frameworks, in particular, were widely used to assess sustainability. The PSR approach was further modified as driving force-state-response (DSR) by the United Nations Conference on Sustainable Development (UNCSD) in 2001 and driving force-pressure-state-impact-response (DPSIR) by the United Nations Environment Programme (UNEP). The CAB approach is based on the economic theory of ‘genuine savings’. Genuine savings is understood as the variation of all natural and man-made capital stocks, evaluated at certain specific accounting prices, which shows that on a path that maximizes the discounted utilitarian sum, a negative value for genuine savings implies that the current level of well-being is not sustainable.

2.4. Links of SD with climate change and climate policy:

A complex relation between climate change, climate policies, and SD exists. Three main linkages can be identified, each of which contains many elements. First, the climate threat constrains possible development paths, and sufficiently disruptive climate change could preclude any prospect for sustainable future. In this perspective, an effective climate response is necessarily an integral objective of an SD strategy. Second, there are tradeoffs between climate responses and broader SD goals, because some climate responses can impose other environmental pressures, have adverse distributional effects, draw resources away from other developmental priorities, or otherwise impose limitations on growth and development. Third, there are multiple potential synergies between climate responses and broader SD objectives. Climate responses may generate co-benefits for human and economic development.

Figure 2 illustrates the normative framework on which a SD path can be grounded on certain values (well-being, equity) and interrelated goals (development and conservation), and the synergies and tradeoffs between SD and climate policy, with procedural equity and iterative learning nurturing each step, from conceptualization to implementation.

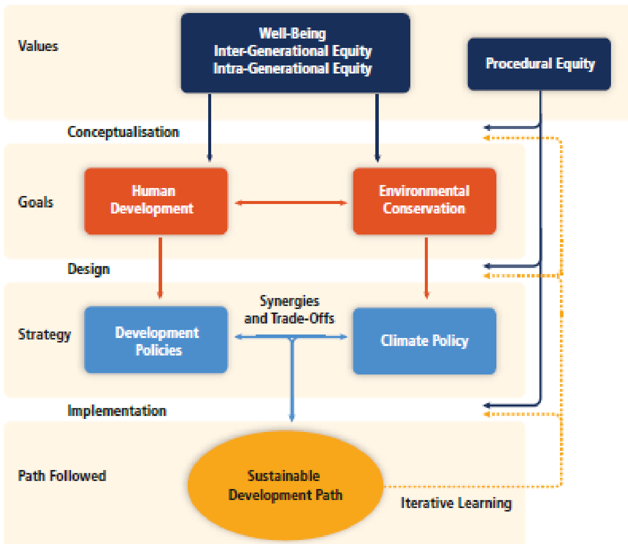

Figure 2. Links between SD, equity, and climate policy

2.5. Determinants, drivers and barriers of SD:

Determinants of SD refer to social processes, properties, and arte-facts, as well as natural resources, which together condition and mediate the course of societal development, and thus the prospects for SD. When determinants facilitate SD they act as drivers and when they constrain it they act as barriers.

The determinants discussed include: the legacy of development relations; governance and political economy; population and demography; human and social capital; behaviour, culture, and values; technology and innovation processes; natural resources; and finance and investment. There are other determinants such as leadership, randomness, or human nature, but they are less amenable to deliberate intervention by policy-makers and other decision makers and so they were excluded.

2.6. Potential implications of mitigation options for sustainable development in agriculture:

There are various potential impacts of agricultural GHG mitigation on sustainable development. Broadly, three constituents of sustainable development have been envisioned as the critical minimum: social, economic, and environmental factors.

Agriculture is a critical sector of the world economy and uses more water than any other sector. In low-income countries, agriculture uses 87% of total extracted water, 74% in middle-income countries and 30% in high-income countries. Through proper institutions and effective functioning of markets, water management can be implemented with favourable outcomes for both environmental and economic goals. Removal of subsidies in the electricity and water sectors might lead to effective water use in agriculture, through adaptation of appropriate irrigation technology, such as drip irrigation in place of tube well irrigation. By careful drainage and effective institutional support, irrigation costs of farmers can also be reduced, thereby improve economic aspects of sustainable development.

An appropriate mix of rice cultivation with livestock, known as integrated annual crop-animal systems, can improve income generation, even in semi-arid and arid areas of the world. For example, this combination of livestock and cropping, especially for rice, found in West Africa, India and Indonesia and Vietnam and this can enhance net income, improve cultivated agro-ecosystems, and enhance human well-being.

Groundwater quality may be enhanced and the loss of biodiversity can be improved by using suitable fertilizers, targeted pesticides and farmyard manure. Better nutrient management and animal husbandry can also improve environmental sustainability.

Controlled overgrazing through pasture improvement has a favorable impact on livestock productivity and slows down desertification. It also provides social security to the poorest people during extreme climatic conditions such as drought (especially in Sub-Saharan Africa). One effective strategy to control overgrazing is the prohibition of free grazing, as was done in China. Halting overgrazing and coupling with improved livelihood options (like fisheries in Syria, Israel and other central Asian countries), can help to reduce poverty and achieve sustainability goals as dry land and desert areas have the highest number of poor people.

Land cover and tillage management could encourage favorable impacts on environmental goals. A mix of horticulture with optimal crop rotations would promote carbon sequestration and could also improve agro-ecosystem function. Conversion of floodplains and wetlands to agriculture could hamper ecological function (reduced water recharge, bioremediation, nutrient cycling, etc.) and therefore, could have an adverse impact on sustainable development goals.

3. Mitigation and Adaptation in different sectors:

3.1. Policies and measures in the case of surface transport

Transport activity is increasing around the world as economies grow. This is especially true in the developing world. Current transportation activity is mainly driven by internal combustion engines powered by petroleum fuels.

The mitigation measures could be use of public transport, walking in smaller distances, cycling and reduction in CO_2 emissions wherever possible and better integrated spatial planning is an important policy element in the transportation sector. Fuel-economy standards or CO_2 standards are to be imposed in reducing GHG emissions. Taxes on vehicle purchase, registration, use and motor fuels, as well as road and parking pricing policies are important determinants of vehicle-energy use and GHG emissions.

The market potential of hydrogen vehicles and Electric vehicles with high efficiency may be improved. Bio-fuels have the potential to replace a substantial part of petroleum products. For

mitigation measures, the hydrogen-powered fuel-cell vehicles have been launched around the globe recently. Though it has little success at present, there is lot of scope for improvement in future.

Air traffic

The fuel efficiency of civil aviation can be improved by a variety of means including technology, operation and management of air traffic. More recently, researchers have begun to address the potential for minimizing the total climate impact of aircraft operations, including ozone impacts, contrails and nitrogen oxides emissions.

The introduction of biofuels could mitigate some of aviation's carbon emissions. Aircraft operations can be optimized for energy use (with minimum CO_2 emissions) by minimizing taxiing time, flying at optimal cruise altitudes, flying minimum-distance great-circle routes, and minimizing holding and stacking around airports.

Marine transport

The mitigation options in marine transport could be replacing old ships by new ships by applying state-of-the-art knowledge, such as hull and propeller design and maintenance. The short-term mitigation potential for operational measures could be route-planning and speed reduction.

Rail transport

The main opportunities for mitigating GHG emissions associated with rail transport are improvement of aerodynamics, reduction of train weight, introducing regenerative braking and on-board energy storage and, of course, mitigating the GHG emissions from electricity generation.

3.2. Policies and measures in the case of electricity sector

The electricity sector has a significant mitigation potential using a wide range of technologies and a wide range of energy-supply mitigation options like fuel switching and power-plant efficiency improvements, nuclear power and renewable energy systems. Other options include advanced nuclear power, advanced renewables, second-generation biofuels and, in the longer term, the possible use of hydrogen as an energy carrier.

Many technologies offer long-term potential for mitigating industrial GHG emissions, but interest has focused on three areas: biological processing, use of hydrogen and nanotechnology.

3.3. Policies and measures in the case of indoor Air pollution

The World Health Organisation ranked indoor air pollution from burning solid fuels as the fourth most important health-risk factor in developing and least developed countries. It has been estimated that half a million children and women die each year in Africa alone from indoor air pollution. A comprehensive study conducted in Ethiopia, Zimbabwe and Kenya showed that those who came from households using wood, dung or straw for cooking were more than twice to have suffered from acute respiratory diseases than those coming from households using LPG, natural gas or electricity. Major health problems associated with indoor air pollution are acute respiratory infection, chronic obstructive lung disease, cancer and pulmonary diseases.

Mitigation Policies and measures aimed at increasing sustainability through reduction of energy use, energy-efficiency improvements, switching from the use of fossil fuels, and reducing the production of process wastes, will result in a simultaneous lowering of GHG emissions and reduced air pollution.

The Johannesburg Plan of Implementation called on all countries to develop more sustainable consumption and production patterns with regard to control of Air Pollution. Policies and measures to promote such pathways will automatically result in a reduction of GHG emissions and be useful to

control air pollution. Toxic emissions such as SO_2 and particulates can have local health impacts as well as potentially wider detrimental environmental impacts.

3.4. Technology transfer

Finally the key element of a successful climate change mitigation program will be the ability of agreement to stimulate the development and transfer of technology without which it may be difficult to achieve emission reductions at a significant scale.

The mechanism of technology transfer projects is included in the establishment and contribution of special funding agencies that disburse money to finance emission reduction projects or adaptation activities. The UNFCCC and the Kyoto Protocol had already included provisions for establishing and funding technology transfer project activities under Article 4.5, although contributions and participation in these projects are mostly voluntary.

4. Mitigation measures:

There are many potential mitigation and adaptive responses available to human societies, ranging from purely technological (e.g., sea defences), through behavioural (e.g., altered food and recreational choices), to managerial (e.g., altered farm practices) and to policy (e.g., planning regulations).

For developing countries, availability of resources and building adaptive capacity are particularly important.

There is a long record of mitigation measures taken to the impacts of weather and climate through many ranges of practices that include crop diversification, irrigation, water management, disaster risk management and insurance etc. But climate change poses novel risks which are often outside the range of experience, such as impacts related to drought, heat waves, accelerated glacier retreat and hurricane intensity. These adaptation measures are undertaken by many public and private organizations through policies, investments in infrastructure and technologies, and behavioural change.

Some examples of mitigations taken with regard to climate change in different occasions are:

- partial drainage of the Tsho Rolpa glacial lake (Nepal);
- changes in livelihood strategies in response to permafrost melt by the Inuit in Nunavut (Canada);
- increased use of artificial snow-making by the Alpine ski industry (Europe, Australia and North America);
- coastal defenses in the Maldives and the Netherlands;
- water management in Australia;
- government responses to heat waves in some European countries.

Some other mitigation measures taken considering the scenarios of future climate change are consideration of sea-level rise in the design of infrastructure such as the Confederation Bridge in Canada and a coastal highway in Micronesia, as well as the shoreline management policies and flood risk measures, in Maine (USA) and the Thames Barrier (UK).

4.1. Mitigation potential and analytical approaches

There are different ways of defining the potential for mitigation and it is therefore important to specify what potential is meant. 'Mitigation Potential' is used to express the degree of GHG reduction that can be achieved by a mitigation option with a given cost per tonne of carbon avoided over a given period, compared with a baseline or reference case. It is measured or expressed as million tonnes of carbon (or CO_2) equivalent emissions avoided with reference to baseline emissions.

4.1.1. Market potential is the mitigation potential based on private costs and private discount rates, which might be expected to occur under forecast market conditions, including policies and measures currently in place, noting that barriers limit actual uptake.

4.1.2. Economic potential is the amount of GHG mitigation, which takes into account social costs and benefits and social discount rates assuming that market efficiency is improved by policies and measures and barriers are removed.

4.1.3. Technical potential. It is the amount by which GHG emissions can be reduced by implementing a technology or practice that was accepted all over world**.** There is no specific reference to costs here.

Studies of market potential can be used to inform policy makers about mitigation potential with existing policies and barriers, while studies of economic potentials show what might be achieved if appropriate new and additional policies were put into place to remove barriers and include social costs and benefits. The economic potential is therefore generally greater than the market potential.

4.1.4. Estimation of mitigation potential

Mitigation potential is estimated using different types of approaches. There are two broad classes – "bottom-up" and "top-down" approaches, which primarily have been used to assess the economic potential.

Bottom-up studies are based on assessment of mitigation options, emphasizing specific technologies and regulations. They are typically sectoral studies taking the macro-economy as unchanged.

Top-down studies assess the economy-wide potential of mitigation options. They use globally consistent frameworks and aggregated information about mitigation options and capture macro-economic and market feedbacks.

Bottom-up studies in particular are useful for the assessment of specific policy options at sectoral level, e.g. options for improving energy efficiency, while top-down studies are useful for assessing cross sectoral and economy-wide climate change policies, such as carbon taxes and stabilization policies.

Both bottom-up and top-down studies indicated that there is substantial economic potential available for the mitigation of global GHG emissions over the coming decades, that could compensate the projected growth of global emissions or reduce emissions below current levels.

4.2. Mitigation practices in Africa:

The low adaptive capacity of Africa is due to the extreme poverty of many Africans, frequent natural disasters such as droughts and floods, agriculture that is heavily dependent on rainfall, as well as macro- and micro-structural problems.

Some of the emerging livelihood adaptation & mitigation practices being observed in some parts of Africa are diversification of livelihood activities, institutional architecture (including rules and norms of governance), adjustments in farming operations, income generation.

The role of migration as an adaptive measure, particularly as a response to drought and flood, is also well known. A detailed study of current crop selection as an adaptation strategy to climate change in Africa shows that farmers select sorghum and maize-millet in the cooler regions of Africa, maize-beans, maize-groundnut and maize in moderately warm regions, and cowpea, cowpea-sorghum and millet-groundnut in hot regions.

The factors that could be used to enhance resilience to shocks such as droughts include: national grain reserves, grain future markets, weather insurance, the role of food price subsidies, cash transfers and school feeding schemes etc.

4.2.1. Food insecurity: the role of climate variability, change and other stressors

It has long been recognized that climate variability and change have an impact on food production. The key recognition in this shifting focus is that there are multiple factors, at all scales, that impact on an individual or household's ability to access sufficient food. These include household income, human health, government policy, conflict, globalization, market failures, as well as environmental issues.

Basing on this, three principal components of food security may be identified:

i. the *availability* of food (through the market and through own production);
ii. adequate purchasing and/or relational power to acquire or *access* food;
iii. the acquisition of sufficient nutrients from the available food, which is influenced by the ability to digest and absorb *nutrients* necessary for human health, access to safe drinking water, environmental hygiene and the nutritional content of the food itself.

Climate variability, such as periods of drought and flood as well as longer-term change, may either directly or indirectly, impact on all these three components in shaping the food security. The potential impacts of climate change on *food access* are due to the changes in Africa's livelihoods and landscape. A trajectory of diversification out of agricultural-based activities – 'deagrarianisation' – has been found in the livelihoods of rural people in many parts of sub-Saharan Africa. Less reliance on food production as a primary source of people's food security runs counter to the assumption that people's food security in Africa derives solely from their own agricultural production.

4.2.2. Indigenous knowledge in mitigation and adaptation in Africa

African communities and farmers have always coped with changing environments. They have the knowledge and practices to cope with adverse environments and shocks. The enhancement of indigenous capacity is a key to the Empowerment of local communities and their effective participation in the development process. People are better able to adopt new ideas when these can be seen in the context of existing practices.

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4.2.3. Uncertainties, confidence levels and unknowns in Africa

• While climate models are generally consistent regarding the direction of warming in Africa, projected changes in precipitation are less consistent.

• The role of land-use and land-cover change (i.e., land architecture in various guises) emerges as a key theme. The links between land-use changes, climate stress and possible feedbacks are not yet clearly understood.

• The contribution of climate to food insecurity in Africa is still not fully understood, particularly the role of other multiple stresses that enhance impacts of droughts and floods and possible future climate change. While drought may affect production in some years, climate variability alone does not explain the limits of food production in Africa. Better models and methods to improve understanding of multiple stresses, particularly at a range of scales, e.g., global, regional and local, and including the role of climate change and variability, are therefore required.

• Several areas of debate and contention, also exist, with particular reference to health, the water sector and certain ecosystem responses, e.g., in mountain environments. More research on such areas is clearly needed.

• Impacts in the water sector, while addressed by global- and regional-scale model assessments, are still relatively poorly researched, particularly for local assessments and for groundwater impacts.

• Several of the impacts and vulnerabilities presented here derived from global models do not currently resolve local level changes and impacts. Developing and improving regional and local-level climate models and scenarios could improve the confidence attached to the various projections.

• Local-scale assessments of various sorts, including adaptation studies, are still focused on understanding current vulnerabilities and adaptation strategies. Few comprehensive, comparable studies are available within regions, particularly those focusing on future options and pathways for adaptation.

• Finally, there is still much uncertainty in assessing the role of climate change in complex systems that are shaped by interacting multiple stressors. Preliminary investigations give some indications of these interactions, but further analysis is required.

5. Mitigation scenarios for agriculture sector:

5.1. Future global trends for agriculture

Agricultural N_2O emissions are projected to increase by 35-60% up to 2030 due to increased nitrogen fertilizer use and increased animal manure production. It was estimated that N_2O emissions will increase by about 50% by 2020 (relative to 1990) (Figure 3).

5.2. Regional trends

According to Figure 3, the Middle East and North Africa, and Sub-Saharan Africa have the highest projected growth in emissions, with a combined 95% increase in the period 1990 to 2020. Sub-Saharan Africa is one of the regions where per-capita food production is either in decline, or roughly constant at a level that is less than adequate. This trend is linked to low and declining soil fertility and inadequate fertilizer inputs. Although slow, the rising wealth of urban populations is likely to increase demand for livestock products. This would result in intensification of agriculture and expansion to still largely unexploited areas, particularly in South and Central Africa (including Angola, Zambia, DRC, Mozambique and Tanzania), with a consequent increase in GHG emissions.

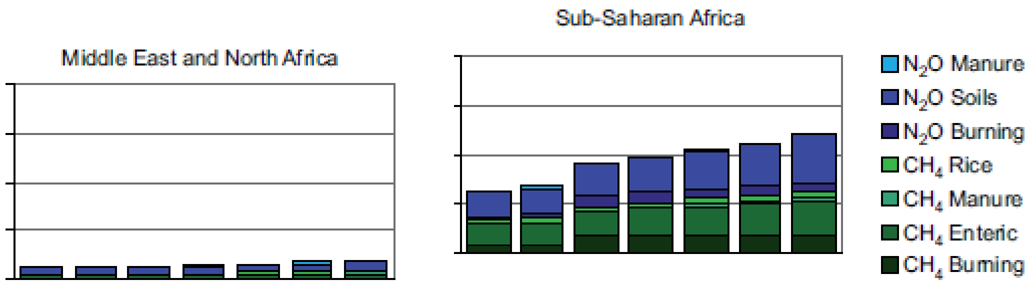

Figure 3: *Estimated historical and projected N_2O and CH_4 emissions in the agricultural sector in the North and sub Saharan Africa during the period 1990-2020.*

5.3. Mitigation technologies and practices

Opportunities for mitigating GHGs in agriculture fall into three broad categories, based on the underlying mechanism:

a. Reducing emissions: Significant amounts of CO2, CH4, or N2O from agriculture releases to the atmosphere can be reduced efficiently by flowing carbon and nitrogen in agricultural ecosystems. For example, practice of adding N more efficiently to crops often reduce N2O emissions and managing livestock by most efficient use of feeds often reduces amounts of CH4.
b. Enhancing removals: Agricultural ecosystems generally hold large carbon reserves, mostly in soil organic matter. Sometimes if these systems lose more carbon, then this lost carbon can be recovered through improved management, by withdrawing from atmospheric CO2. Any practice that increases the photosynthetic input of carbon and slows the return of stored carbon to CO2 via respiration, fire or erosion will increase carbon reserves, thereby ‘sequestering’ carbon or building carbon ‘sinks’. Significant amounts of soil carbon can be stored in this way and through many other practices suited to local conditions. Significant amounts of vegetative carbon can also be stored in agro-forestry systems or other perennial plantings on agricultural lands. Agricultural lands also remove CH4 from the atmosphere by oxidation but this effect is small compared to other GHG fluxes.
c. Avoiding (or displacing) emissions: Crops and residues from agricultural lands can be used as a source of fuel, either directly or after conversion to fuels such as ethanol or diesel. The net benefit of these bio-energy sources to the atmosphere is equal to the fossil-derived emissions displaced, less any emissions from producing, transporting, and processing.

5.4. Cropland management

Croplands offer many opportunities to impose practices that reduce net GHG emissions. Mitigation practices in cropland management include the following.

a. Agronomy: Improved agronomic practices that increase yields and generate higher inputs of carbon residue can lead to increased soil carbon storage. Examples of such practices include: using improved crop varieties; extending crop rotations, notably those with perennial crops that allocate more carbon below ground; and avoiding or reducing use of bare (unplanted) fallow lands. Emissions per hectare can also be reduced by adopting cropping systems with reduced reliance on fertilizers, pesticides and other inputs. An important example is the use of rotation with legume crops which reduce reliance on external N inputs although legume-derived N can also be a source of N2O. Another group of agronomic practices are those that provide temporary vegetative cover between successive agricultural crops, or between rows of tree or

vine crops. These 'catch' or 'cover' crops add carbon to soils and may also extract plant available N unused by the preceding crop, thereby reducing N2O emissions.

b. Nutrient management: As plants cannot use the N fertilizers hundred percent, efficient use of N fertilizers isimportant. Practices that improve efficient use of N include: adjusting application rates based on precise estimation of crop needs (e.g., precision farming); using slow- or controlled-release fertilizer forms or nitrification inhibitors (which slow the microbial processes leading to N2O formation); applying N when least susceptible to loss, often just prior to plant uptake (improved timing); placing the N more precisely into the soil to make it more accessible to crops roots; or avoiding N applications in excess of immediate plant requirements.
c. Tillage/residue management: Advances in weed control methods and farm machinery now allow many crops to be grown with minimal tillage (reduced tillage) or without tillage (no-till). These practices are now increasingly used throughout the world.
d. Water management: Using more effective irrigation measures can enhance carbon storage in soils through enhanced yields and residue returns.
e. Rice management: Cultivated wetland rice soils emit significant quantities of methane. Emissions during the growing season can be reduced by various practices. For example, draining wetland rice once or several times during the growing season reduces CH4 emissions. Rice cultivars with low exudation rates could offer an important methane mitigation option. In the off-rice season, methane emissions can be reduced by keeping the soil as dry as possible to avoid water logging. Methane emissions can be reduced by adjusting the timing of organic residue additions (e.g., incorporating organic materials in the dry period rather than in flooded periods; by composting the residues before incorporation, or by producing biogas for use as fuel for energy production.
f. Agro-forestry: Agro-forestry is the production of livestock or food crops on land that also grows trees for timber, firewood, or other tree products. Planting trees may increase soil carbon sequestration.
g. Land cover (use) change: One of the most effective methods of reducing emissions is often to allow or encourage the reversion of cropland to another land cover, typically one similar to the native vegetation. Such land cover change often increases carbon storage. For example, converting arable cropland to grassland typically results in the accrual of soil carbon because of lower soil disturbance and reduced carbon removal in harvested products. Compared to cultivated lands, grasslands may also have reduced N2O emissions from lower N inputs, and higher rates of CH4 oxidation. Similarly converting grasslands to crop lands results in rapid accumulation of soil carbon (removal of atmospheric CO2).

5.5. Grazing land management and pasture improvement

Grazing lands occupy much larger areas than croplands and are usually managed less intensively. The following are examples of practices to reduce GHG emissions and to enhance removals:

a. Grazing intensity: The intensity and timing of grazing can influence the removal, growth, carbon allocation, and flora of grasslands, thereby affecting the amount of carbon accrual in soils. Carbon accrual on optimally grazed lands is often greater than on ungrazed or overgrazed lands.
b. Increased productivity: (including fertilization): Like croplands, carbon storage in grazing lands can be improved by a variety of measures that promote productivity. For example, use of fertilizer or organic amendments increases plant litter returns and, hence, soil carbon storage. Irrigating grasslands, similarly, can promote soil carbon gains.

c. Nutrient management: Management of nutrients on grazing lands, however, may be complicated by deposition of faeces and urine from livestock, which are not as easily controlled nor as uniformly applied as nutritive amendments in croplands.
d. Fire management: On-site biomass burning contributes to climate change in several ways. Firstly, it releases GHGs. Secondly, it generates hydrocarbon and reactive nitrogen emissions, which react to form tropospheric ozone which is a harmful GHG for troposphere. Thirdly, fire produces huge smoke aerosols which can have either warming or cooling effects on the atmosphere; the *net* effect is thought to be positive radiative forcing. Fourth, fire reduces the albedo of the land surface for several weeks, causing warming. So mitigation actions involve reducing the frequency or intensity of fires typically leads to increased tree and shrub cover, resulting in a CO2 sink in soil and biomass.
e. Species introduction: Introducing grass species with higher productivity, or carbon allocation to deeper roots, has been shown to increase soil carbon. For example, establishing deep-rooted grasses in savannahs has been reported to yield very high rates of carbon accrual.

5.6. Restoration of degraded lands

A large proportion of agricultural lands has been degraded by excessive disturbance, erosion, organic matter loss, salinization, acidification, or other processes that curtail productivity. Often, carbon storage in these soils can be partly restored by practices that reclaim productivity including: re-vegetation (e.g., planting grasses); improving fertility by nutrient amendments; applying organic substrates such as manures, biosolids, and composts; reducing tillage and retaining crop residues; and conserving water.

5.7. Livestock management

Livestock, predominantly cattle and sheep, are important sources of CH4, accounting for about one-third of global anthropogenic emissions of this gas. The methane is produced primarily by enteric fermentation. All livestock generate N2O emissions from manure as a result of excretion of N in urine and dung. Practices for reducing CH4 and N2O emissions from this source fall into three general categories: improved feeding practices, use of specific agents or dietary additives; and long term management changes and animal breeding.

a. Improved feeding practices: Methane emissions can be reduced by feeding more concentrates, normally replacing forages.
b. Specific agents and dietary additives: A wide range of specific agents, mostly aimed at suppressing methanogenesis, has been proposed as dietary additives to reduce CH4 emissions:
- Ionophores are antibiotics that can reduce methane emissions
- Novel plant compounds such as condensed tannins, saponins or essential oils may have merit in reducing methane emissions.
- Probiotics, such as yeast culture, have shown only small, insignificant effects
- Propionate precursors such as fumarate or malate reduce methane formation by acting as alternative hydrogen acceptors.

c. Longer-term management changes and animal breeding: Increasing productivity through breeding and better management practices, such as reduction in the number of replacement calfs, often reduces methane output per unit of animal product.

5.8. Manure management

Animal manures can release significant amounts of N2O and CH4 during storage, but the magnitude of these emissions varies. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling, use of solid covers, mechanically separating solids from slurry, or by capturing the

emitted CH4 in tanks. The manures can also be digested anaerobically to maximize CH4 retrieval as a renewable energy source. To some extent, emissions from manure can be curtailed by composting.

5.9. Bioenergy

A wide range of agricultural crops, grain, crop residue, cellulosic crops and various tree species can be used as sources of alternative energy to displace fossil fuels. These products can be burned and processed further to generate liquid fuels such as ethanol or diesel fuel. The CO_2 released during this burning is fresh and so can be used by plants for photosynthesis. Sub-Saharan Africa, and Eastern Europe are promising regions for bio-energy.

5.10. Technical potential for GHG mitigation in agriculture

There have been numerous attempts to assess the technical potential for GHG mitigation in agriculture. Most of these have focused on soil carbon sequestration.

Estimates of the IPCC Second Assessment Report (SAR, IPCC, 1996) suggested that 400-800 MtC/yr (equivalent to about 1400-2900 $MtCO_2$- eq/yr) could be sequestered in global agricultural soils with a finite capacity saturating after 50 to100 years. In addition, SAR concluded that 300-1300 MtC (equivalent to about 1100- 4800 $MtCO_2$-eq/yr) from fossil fuels could be compensated by using 10 to 15% of agricultural land to grow energy crops; with crop residues potentially contributing 100-200 MtC (equivalent to about 400-700 $MtCO_2$-eq/yr) to fossil fuel compensates if recovered and burned.

SAR also estimated that CH_4 emissions from agriculture could be reduced by 15 to 56%, mainly through improved nutrition of ruminants and better management of paddy rice, and that improved management could reduce N_2O emissions by 9-26%.

The global technical potential for mitigation options in agriculture by 2030, considering all gases, was estimated to be about 5500-6000 $MtCO_2$-eq/yr. From figure 4,it is about 89% is from soil carbon sequestration, about 9% from mitigation of methane and about 2% from mitigation of soil N2O emissions. The total mitigation potential per region is presented in Figure 5. The change in global Economic mitigation potential with increasing carbon price for each practice is shown in Figure 6.

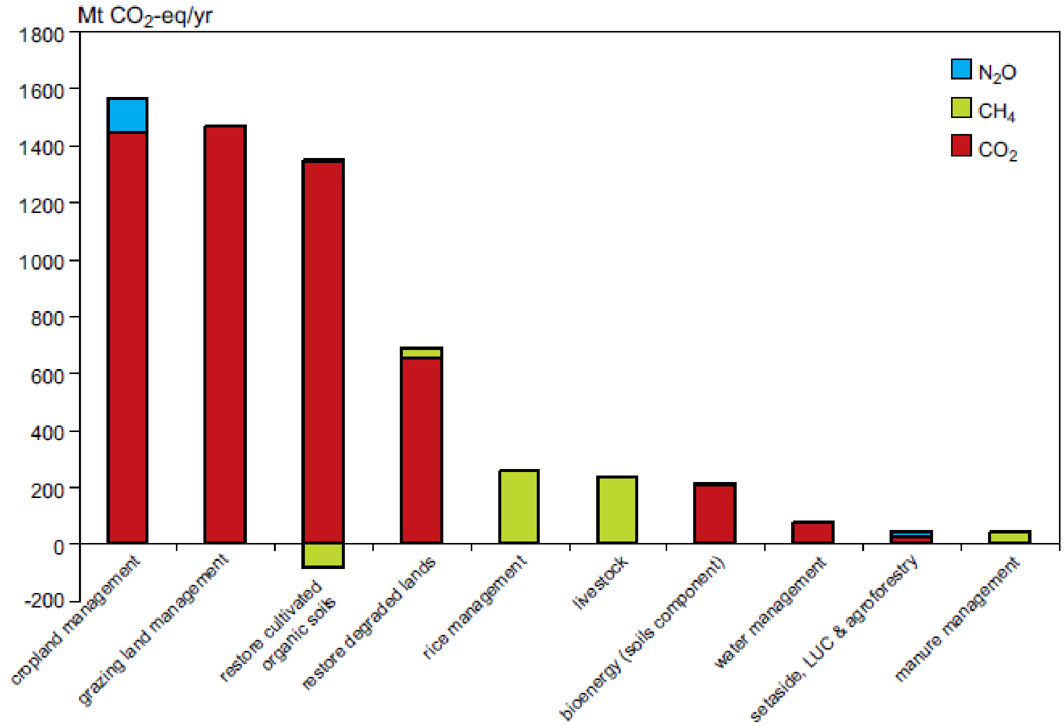

Figure 4: *Global technical mitigation potential by 2030 for each agricultural management practice showing the impacts of each practice on each GHG.* Note: It is based on the B2 scenario though the pattern is similar for all SRES scenarios.

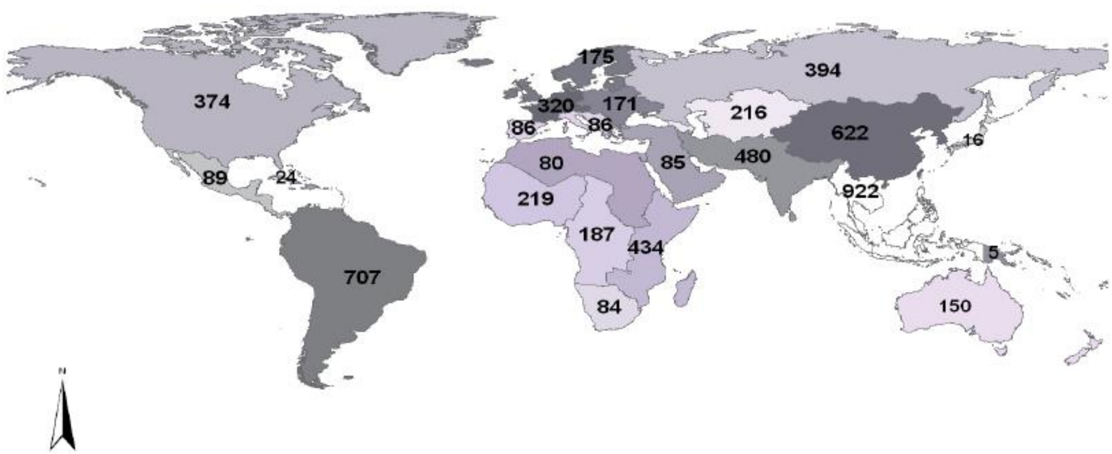

Figure 5: The number in each zone indicates the mean estimate of **t***otal technical mitigation potential (all practices, all GHGs: MtCO2-eq/yr) by 2030.* Note: It is based on the B2 scenario though the pattern is similar for all SRES scenarios. Note the value for Ethiopia is 434 *MtCO2-eq/yr.*

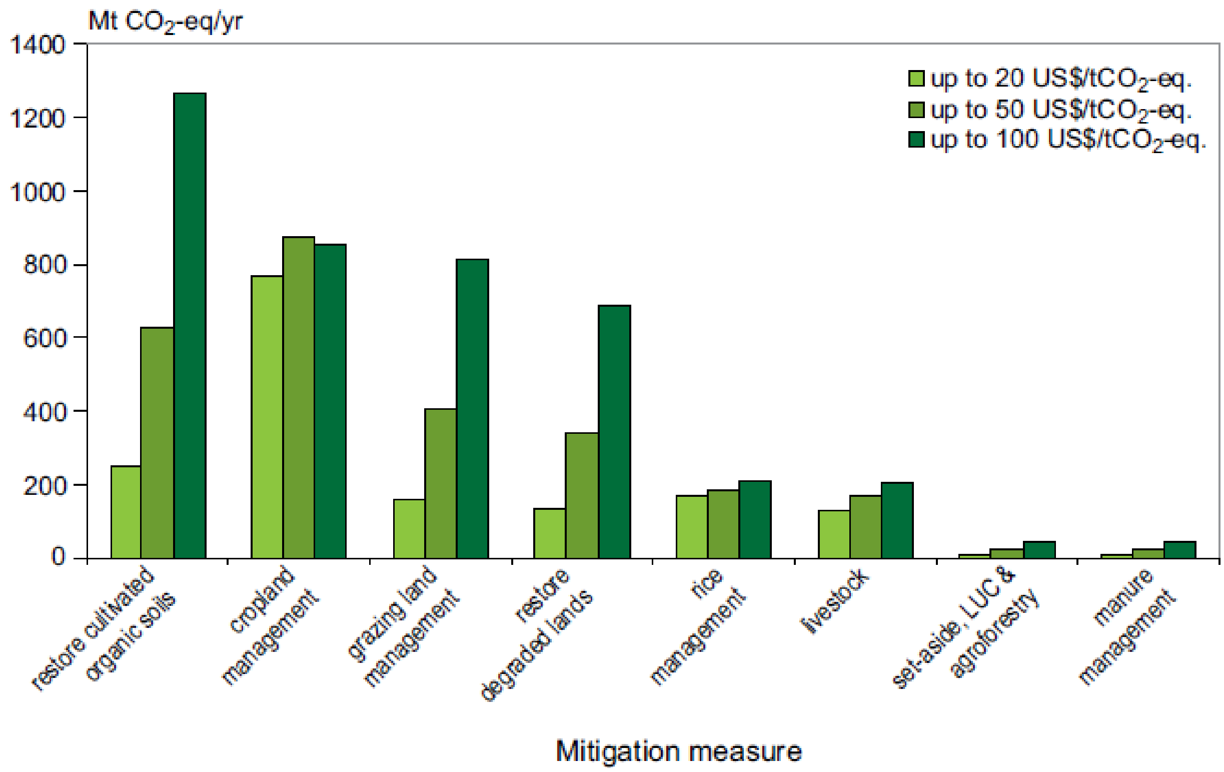

Figure 6: *Economic potential for GHG agricultural mitigation by 2030 at a range of prices of CO_2-eq.* Note: Based on B2 scenario, although the pattern is similar for all SRES scenarios.

6. Policies, Instruments and Co-operative Arrangements

This chapter synthesizes information on policies, instruments and co-operative arrangements, focusing mainly on new information. It reviews national policies, international agreements and initiatives of sub-national governments, corporations and non-governmental organizations (NGOs).

Article 4 of the United Nations Framework Convention on climate change (UNFCCC) commits all Parties to formulate, implement, publish and regularly update national and regional programmes containing measures that will result in the mitigation of climate change by addressing anthropogenic emissions of greenhouse gases (GHGs) by sources and removals by sinks.

6.1. National policies

A wide variety of national policies and measures are available to governments to limit or reduce greenhouse gas (GHG) emissions. These include regulations and standards, taxes and charges, tradable permits, voluntary agreements, subsidies, financial incentives, research and development programmes and information instruments. Other policies, such as those affecting trade, foreign direct investment, consumption and social development goals, can also affect GHG emissions. Climate change policies, if integrated with other government policies, can contribute to sustainable development in developed and developing countries.

Four main criteria are widely used by policymakers to select and evaluate policies. They are environmental effectiveness, cost-effectiveness, distributional effects (including equity) and institutional feasibility. Other more specific criteria, such as effects on competitiveness and administrative feasibility, are generally considered within these four.

In practice, climate-related policies are seldom applied in complete isolation, as they overlap with other national polices relating to the environment, forestry, agriculture, waste management, transport and energy and, therefore, in many cases require more than one instrument.

6.2. International agreements

The UNFCCC and Kyoto Protocol are the two long-term international environmental programs towards the implementation of an international response strategy to combat climate change.

The UNFCCC was adopted in May 1992 in New York and opened for signature at the 'Rio Earth Summit' in Rio de Janeiro (South America) a month later. It entered into force in March 1994 and has achieved ratification by 189 countries of the 194 UN member states. 'The ultimate objective of this Convention is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner'.

The Kyoto Protocol's most notable achievements are the stimulation of an array of national policies, the creation of a carbon market and the establishment of new institutional mechanisms. The Kyoto Protocol is currently constrained by the modest emission limits. The Kyoto Protocol has also stimulated the development of emissions trading systems, though a fully global system has not been implemented. The Clean Development Mechanism (CDM), in particular, has created a large project pipeline and mobilized substantial financial resources, but it has faced methodological challenges in terms of determining baselines and additionality.

Goals determine the extent of participation, the stringency of the measures and the timing of the actions. For example, to limit the temperature increase to 2°C above pre-industrial levels, developed countries would need to reduce emissions in 2020 by 10–40% below 1990 levels and in 2050 by approximately 40–95%.

6.3. Types of policies, measures, instruments and co-operative arrangements

A variety of policies, measures, instruments and approaches are available to national governments to limit the emission of GHGs; these include regulations and standards, taxes and charges, tradable permits, voluntary agreements (VAs), informational instruments, subsidies and incentives, research and development and trade and development assistance. These may be implemented at the national level, sub-national level or through bi-lateral or multi-lateral arrangements, and they may be either legally binding or voluntary and either fixed or changeable. Other policies, such as those affecting trade, foreign direct investments and social development goals can also affect GHG emissions. In general, climate change policies, if integrated with other government policies, can contribute to sustainable development in both developed and developing countries.

The following Box provides a brief definition of each instrument.

Regulations and Standards: These specify the abatement technologies (technology standard) or minimum requirements for pollution output (performance standard) that are necessary for reducing emissions.

Taxes and Charges: A levy imposed on each unit of undesirable activity by a source.

Tradable Permits: These are also known as marketable permits or cap-and-trade systems. This instrument establishes a limit on aggregate emissions by specified sources, requires each source to hold permits equal to its actual emissions and allows permits to be traded among sources.

Voluntary Agreements: An agreement between a government authority and one or more private parties with the aim of achieving environmental objectives or improving environmental performance beyond compliance to regulated obligations. Not all VAs are truly voluntary; some include rewards and/or penalties associated with participating in the agreement or achieving the commitments.[1]

Subsidies and Incentives: Direct payments, tax reductions, price supports or the equivalent thereof from a government to an entity for implementing a practice or performing a specified action.

Information Instruments: Required public disclosure of environmentally related information, generally by industry to consumers. These include labelling programmes and rating and certification systems.

Research and Development (R&D): Activities that involve direct government funding and investment aimed at generating innovative approaches to mitigation and/or the physical and social infrastructure to reduce emissions. Examples of these are prizes and incentives for technological advances.

Non-Climate Policies: Other policies not specifically directed at emissions reduction but which may have significant climate-related effects.

1 Voluntary Agreements (VAs) should not be confused with voluntary actions which are undertaken by govern-ment agencies at the sub-national level, corporations, NGOs and other organizations independent of national government authorities. See Section 13.4.

6.4. Criteria for policy choice:

Four principal criteria for evaluating environmental policy instruments are available. They are Environmental effectiveness, Cost-effectiveness, Distributional considerations and Institutional feasibility.

The main goal of policy instruments related to environmental effectiveness is to reduce the negative impact of human action on the environment.

The cost-effectiveness of a policy is a key decision parameter in a world with scarce resources. Given a particular environmental quality goal, the most cost-effective policy is the one which achieves the desired goal at the least cost. While some researchers argue that reductions should be postponed until low-cost technologies are available, others argue that necessary decisions have to be made today to avoid a ‘lock-in’ to an emission intensive pathway that would be expensive to leave at a later time point.

The distributional considerations of climate change policies relate largely to equity. Equity and fairness may be perceived in terms of capacity and need which are the basic principles of fairness for a climate policy regime. For example, a policy that focuses the regulatory burden on a low-income group may not be a more popular one as majority will suffer. An interesting policy in this regard is the Australian climate policy which is controlled by industrialists of the country in their favor.

Institutional feasibility of an environmental policy decision depends on local, cultural, economical and public support. Environmental policies that are well adapted to existing institutional constraints have a high degree of institutional feasibility. Instrument design and implementation must take political realities into account. In reality, policy choices must be both acceptable to a wide range of stakeholders and supported by institutions, notably the legal system. Then only the policy will be implemented easily. Otherwise the policy will fail.

6.5. Regulations and standards

A regulatory standard specifies with a certain degree of precision the action that a firm or individual must undertake to achieve environmental objectives. Two broad classes of regulatory standards are technology and performance standards. Technology standards mandate specific pollution abatement technologies or production methods, while performance standards mandate specific environmental outcomes per unit of product. In this context, where a technology standard might mandate specific CO_2 capture and storage methods on a power plant, a performance standard would limit emissions to a certain number of grams of CO_2 per kilowatt-hour of electricity generated. Similarly, a product standard would be that the refrigerators operate minimally at a specified level of efficiency, while a technology standard would involve making the refrigerator efficiency requirement.

With regard to regulatory standards of buildings, China introduced a new building construction policy that includes energy efficiency standard for buildings in 2006. It requires to use energy efficient building materials and to adopt energy-saving technology in heating, air conditioning, ventilation and lighting systems in civil buildings.

In order to decrease the amount of carbon emitted into the atmosphere, the options available to the industries are the use of substitute fuels with lower life-cycle carbon content, or the more efficient use of existing fuels by improving combustion technology, or switching to hybrid technologies. Though most industrialized countries agreed to cut back their emissions by a collective average of 5.2 percent of 1990 level emissions, International agreements felt that this is not sufficient and felt further agreements.

6.6. Taxes and charges

An emission tax on GHG emissions requires individual emitters to pay a fee for every tonne of GHG released into the atmosphere.

A key element of the UK's climate policy is a climate levy. The levy is paid by energy users and aims to encourage the use of renewable energy. An 80% discount can be secured if particular industry participates in a negotiated 'climate change agreement' to reduce emissions relative to an established baseline. Any company over-complying with its agreement can trade the resulting credits in the UK emissions trading scheme, along with renewable energy certificates.

6.7. Voluntary agreements (VAs):

Voluntary agreements (VAs) are agreements between a government authority and the private parties to improve environmental performance beyond compliance to the regulated obligations. Voluntary agreements can be used when other instruments face strong political opposition. With the help of VAs, firms may enjoy lower legal costs, enhance their reputation and improve their relationships with society and shareholders. Societies gain to the extent that firms translate goals into concrete business practices and persuade other firms to follow their example.

Thus Voluntary agreements are often favored by industry because of their flexibility and potentially lower costs. Though the benefits of VAs for individual companies and for society are significant, these are often opposed by environmental groups because of their lack of accountability and enforcement with regard to climate change. An instrument that works well in one country may not work well in another country due to different social, cultural, economical, traditional norms and institutions. So a policy related to a specific region may be required along with a national policy.

6.8. Annex I & Non Annex I Parties:

Under the Kyoto protocol agreement, the signatory countries were divided into two categories: Annex I and Non-Annex I parties. Annex I Parties are committed to individual, legally-binding targets to

limit or reduce their greenhouse gas emissions. The targets cover emissions of the six main greenhouse gases, namely: Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Hydrofluorocarbons (HFCs); Perfluorocarbons (PFCs); and Sulphur hexafluoride (SF_6). It was agreed that developed countries would jointly reduce their net emissions of these six greenhouse gases by 5.2 percent during the period 2008-12 with respect to the emission levels of 1990. The Protocol does not list separate targets for each individual gas but instead a combined target for all the gases, expressed in terms of CO_2 equivalence. On the other hand Non-Annex I countries do not have obligations to reduce or limit the greenhouse gas emissions but can voluntarily do so.

The maximum amount of emissions (measured as equivalent to CO_2) that a Party (country) can emit over the commitment period, in order to comply with its emission target, is known as Party's assigned amount. To achieve their targets, Annex I Parties must put in place domestic policies and measures. The Protocol provides an indicative list of policies and measures that might help mitigate climate change and promote sustainable development. Parties may compensate their emissions by removing the greenhouse gases from the atmosphere by carbon sinks through the land use, land-use change and forestry (LULUCF) sector. However, only certain activities of LULUCF are eligible. These are afforestation, reforestation and deforestation and forest management, cropland management, grazing-land management and re-vegetation. The main objective behind these reductions is to stabilize the concentration of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate change.

Under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), industrialized countries (Annex I parties) committed to reduce their greenhouse gas emissions by an average of 5.2 % relative to their 1990 level emissions by 2008–12. In order to achieve these goals it has been agreed by all parties to sincerely work for achieving the 'goals' and regularly 'participate' in the meetings called by UNFCCC for explaining their sincerity in working for reduction of targets.

Though most important tiers are Annex I and non-Annex I, there are also special arrangements for economies in transition as well as for least developed countries. Figure 3 shows the groupings of countries under the UNFCCC, OECD (Organization for Economic Cooperation and Development) and EU (European Union). The allocation of states into tiers can be made according to quantitative or qualitative criteria or 'ad hoc'. Later states can "graduate"(uplift their position) from one tier of commitments to the next. Graduation is linked to the meeting of quantitative thresholds for certain parameters that have been predefined in the agreement, such as emissions, cumulative emissions, GDP per capita, relative contribution to temperature increase or other measures of development, such as the human development index.

Annex I of the UNFCCC, includes: Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Union, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, and United States.

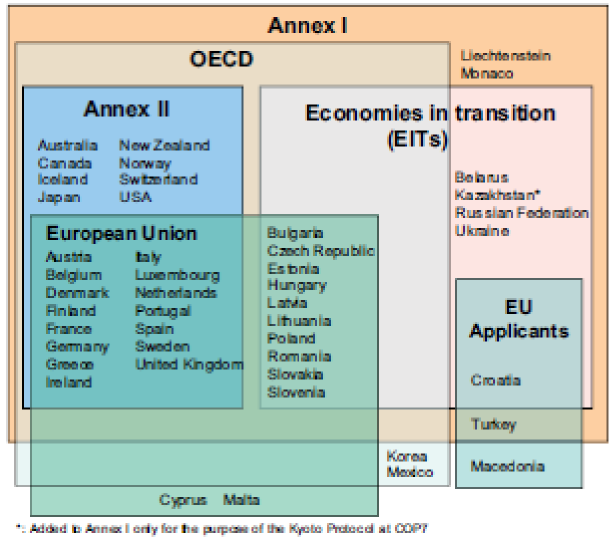

Fig.3. Present country groupings under the UNFCCC, OECD and EU

6.9. The Kyoto Protocol:

The world's primary international agreement on combating global warming is the Kyoto Protocol, an amendment to the United Nations Framework Convention on Climate Change (UNFCCC), negotiated in 1997 that took effect on February 16, 2005. The protocol now covers more than 175 countries and over 55 percent of global greenhouse gas emissions. As of 2007, the United States (historically the world's largest greenhouse gas emitter), Australia, and Kazakhstan had not ratified the treaty because of the exclusions of developing countries from emissions reduction. China and India have ratified the treaty, but as developing countries, are exempt from its provisions. This treaty expires in 2012, and international talks began in May 2007 on a treaty to succeed the current one. Increased awareness of the scientific findings surrounding global warming has resulted in political and economic debate. Poor regions, particularly in Africa, appear at greatest risk from the suggested effects of global warming, while their actual emissions have been negligible compared to the developed world.

After the Kyoto Protocol entered into force on February16, 2005, it is legally binding on countries that ratify the agreement. In the initial negotiations, the United States voluntarily accepted a more ambitious target, promising to reduce emissions to 7 percent below 1990 levels; the European Union, which had wanted a much tougher treaty, committed for 8 percent; and Japan, for 6 percent. Since the adoption of the Kyoto Protocol, 175 countries have ratified it. The protocol sketched out the basic features of its mechanisms and compliance system, but did not explain the all-important rules of how they would operate.

Though the United States has not ratified the Kyoto Protocol, the government has established a comprehensive policy to slow the growth of emissions with voluntary and incentive-based programs, strengthen institutional advancement of climate technologies and climate science, and enhance international cooperation.

In February 2002, the U.S. government announced a comprehensive strategy to reduce the greenhouse gas intensity of the American economy by 18 percent during 2002–12, preventing the release of more than 100 million metric tons of carbon- equivalent emissions to the atmosphere (annually) by 2012 and more than 500 million metric tons (cumulatively) during 2002–12.

A core challenge in addressing global climate change is arriving at multilateral arrangements ensuring adequate effort by all major economies to moderate and reduce their greenhouse gas (GHG) emissions. Thus far, the multilateral effort has relied most heavily on a particular form of commitment-economy-wide emission targets.

Developed countries agreed to voluntary the targets under the UNFCCC, and most of the others later agreed to bind for the targets under the Kyoto Protocol. Most developing countries, however, view quantified emission limits as a potential cap on their growth and are unlikely to accept binding targets in a post-2012 climate agreement.

At the World Conference on Disaster Reduction, The Hyogo Framework for action signed in January 2005 by 168 countries details steps to reduce the impact of natural hazards on populations. It assesses disaster capabilities and needs and incorporates risk reduction strategies and adaptations associated with existing climate variability and future climate change, including risks from geological hazards such as earthquakes and landslides. The result has been 40 countries adjusting national policies to give priority to disaster risk reduction.

The mission of the Millennium Development Goals is to alleviate poverty by integrating sustainable development into national policies and prevent the loss of natural resources. These goals allow countries to determine their own priorities. One way of doing this is by creation of model forests to show how sustainability practices can have a positive impact on human life and to reverse environmental degradation with conservation and reforestation.

When the governments adopted the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCC), it was quite obvious that its commitments would not be sufficient to seriously tackle climate change. At the Conference of Parties (COP) 1 (Berlin, March/April 1995), in a decision known as the Berlin Mandate, parties launched a new round of talks to decide on stronger and more detailed commitments for industrialized countries. After two and a half years of intense negotiations, the Kyoto Protocol was adopted at COP 2 in Kyoto, Japan, on December 11, 1997. The Kyoto Protocol was open for signatures on that day and countries have ratified the protocol and the treaty expired in 2012. But some of the major countries such as the United States and Australia have not ratified the Kyoto Protocol. Big, developing countries such as India and China are part of the protocol, but are not required to cut back any emissions under this treaty (based on the rationale that developing countries should be given a chance for development). This has made the treaty controversial and, so far, the targets have not been fixed. This is based on the principle of common, but differentiated responsibilities, as most of the emissions to be reduced (or blamed for today's climate change) were produced historically (during the industrialization era when most the developing countries did not produce emissions) or originate in developed countries. Per capita emissions in developing nations are

still relatively low compared to the developed nations, and the share of global emissions originating in developing countries will grow to meet their developmental and growth needs.

As Kyoto protocol expired in 2012, COP 21 (Conference of Parties 21st meeting) was held in Paris (France) during November 23-27, 2015 for renewal of Kyoto protocol agreements and for different agreements and commitments by all parties towards climate change mitigation measures.

The United States argued that the developing countries should also be bound by limiting their emissions, but the Kyoto Protocol did not impose any restrictions on them. Developing countries, on the other hand, felt that their development was hampered because the colonial powers prevented their development by exploiting their natural resources and selling their finished products to the developing countries hence preventing development of industry there. Now that they are free to carry on their development, no limits should be imposed on their emission levels, because of their heavy dependence on fossil fuel. Another point of difference between the developed and developing nations was whether to consider the absolute value or the per capita value of emissions as there is a great difference between the two and hence, the controversy still persists.

Many agreements contain provisions for establishing and maintaining supporting institutions. These perform tasks as varied as serving as repositories for specific, agreement-related data, facilitating or adjudicating compliance, serving as clearing houses for market transactions or information flows, to manage financial arrangements. In addition, most agreements have provisions in case of non-compliance. These include binding and nonbinding consequences and may be facilitative or more coercive in nature.

To assist countries in attaining these reduction targets, the Kyoto protocol created three flexible mechanisms. These mechanisms allow countries with reduction commitments to achieve their targets by acquiring credits from emissions reduced or avoided in other countries, where it may be more cost-effective to do so. The three mechanisms of the Kyoto Protocol are: Emissions Trading, Joint Implementation, and the Clean Development Mechanism.

Under Kyoto's international Emission Trading System (ETS), emission allowances may be traded between governments of non-Annex I parties if a surplus occurs in one country. Extensive rules have been agreed upon to ensure that credits created under these project mechanisms actually represent the emissions reduced.

The United States and Australia have not ratified the Kyoto Protocol; even though they agreed to specific reduction targets like the other Annex I parties did in 1997 when the protocol was adopted. Therefore, they are parties to the UNFCCC, but are not parties to the Kyoto Protocol and cannot participate in its mechanisms. Because global warming is a result of accumulated emissions in the atmosphere and non-industrialized countries have historically contributed little to the problem. So developing countries do not have any reduction commitments under the protocol. It was therefore agreed that industrialized countries, which have greater responsibility and capability, should take the lead in reducing emissions.

The Kyoto Protocol thus is a historical milestone, as it is the first international agreement to set targets to reduce greenhouse gas emissions to tackle climate change. The Protocol sketches out the basic features of its mechanisms and compliance system, but did not flesh out the all-important rules of

how they would operate. The 1997 Kyoto Protocol shares the UNFCCC's objectives, principles, and institutions, but significantly strengthens the UNFCCC by setting targets to limit green house gases.

6.9.1. Accounting under Flexible Mechanisms:

To ensure that emission reductions bought and sold through the flexible mechanisms are measurable and real, the Kyoto protocol establishes specific rules and accounting procedures for each of the flexible mechanisms. Emission reductions under any of the three flexible mechanisms generate a specific kind of unit that may be added to or subtracted from a party's assigned amount. Each unit is equal to one metric ton of emissions. All units are fungible (exchangeable), but have different names so they can be traced in the International Transaction Log, kept by the UNFCCC secretariat.

6.9.2. Emission Trading System (ETS):

The ETS was originally designed to meet the targets set by the Kyoto Protocol. Its objective is to stabilize the greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. In the Kyoto Protocol, mechanisms such as International Emissions Trading (IET), Joint Implementation (JI) and the Clean Development Mechanism (CDM) provide options for members to fulfill their targets. IET provides the trading of assigned amount of units (AAUs) between Annex I Parties in the Kyoto Protocol, JI enables Annex I parties to get credits for joining projects to reduce emissions, CDM enables Annex I parties to get credit for projects resulting in emissions reductions in non-Annex I parties.

Under Kyoto's international Emission Trading System (ETS), emission allowances may be traded between governments of non-Annex I parties if a surplus occurs in one country. In other words, a country or a private or public entity within a country that reduces or avoids emissions more than it is required, may sell its emission reductions as credits to another country or entity that has not reduced its own emissions. Because greenhouse gases, in contrast to local pollutants, are uniformly distributed in the atmosphere within a week, it does not matter where the source of emissions is located. However, the cost of reducing or avoiding emissions may vary greatly. Only countries with emission reduction targets under the protocol have "quantified emission limitation and reduction commitments," known as QELRCs, calculated and quantified as an "assigned amount." The total amount of emissions that each country with QELRCs can release 2008–12 (the first commitment period) must not exceed its assigned amount. Because emissions fluctuate from year to year, depending on the weather and economic cycles, an average over several years was chosen to check compliance with the reduction commitments. These are restrictions on a country's level of emissions, based on voluntarily adopted targets that collectively amount to a slightly more than 5 percent reduction relative to emissions in 1990. If a party exceeds its reduction target by cutting back on its emissions more than the amount specified in its QELRCs, it might sell its excess units or, under some circumstances, carry them over to the next commitment period. The QELRCs cover emissions of six greenhouse gases including: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), Hydrofluorcarbons (HFCs), Perfluorocarbons (PCFs), and Sulfur hexafluoride (SF6).]. A total of 39 countries have QELRCs, and they are listed in Annex B (or AnnexI) of the protocol with their respective targets.

Under Emissions Trading, Annex I parties may trade assigned amount units (AAUs) issued on the basis of their assigned amount, or Removal Units (RMUs) issued on the basis of land use, land-use change, and forestry (LULUCF) activities (also known as carbon sinks), with other Annex I parties. They may also trade units acquired under the other flexible mechanisms. Because trading in emissions may be

highly profitable, and given that enforcement of compliance under an international environmental regime could be weak, countries agreed to maintain in their inventories a certain level of credits, called the commitment period reserve. Emissions-trading is set out in Article 17 of the Kyoto Protocol.

6.9.3. Joint Implementation (JI):

Emission reductions achieved through projects between Annex I countries are called Joint Implementation; while emission reduction projects located in non-Annex I countries are called CDM projects.

Joint Implementation (JI) actually refers to credits acquired from projects that reduce or avoid emissions or enhance removals by sinks undertaken mainly in countries with economies in transition (EITs), namely central and eastern European countries that were part of the former Soviet Union. These countries are also Annex I countries, and have reduction commitments under the protocol. Credits traded under JI are recorded as Emission Reduction Units (ERUs). Because both parties involved in the transaction have reduction commitments and are therefore required to report on their overall level of emissions, the rules applied are less complicated than for Clean Development Mechanism (CDM) projects, where the host country has no reduction commitments. The basic principles of JI are defined in Article 6 of the Kyoto Protocol. The CDM is similar to Joint Implementation in that both involve undertaking specific project activities.

6.9.4. Clean Development Mechanism (CDM):

However, the CDM allows countries with reduction commitments to invest in a developing country (non Annex I) in projects that reduce or avoid emissions, or enhance removals by sinks, and to use the resulting credits to meet its commitments. The CDM, therefore, is the only mechanism with a worldwide reach, and its purpose is two fold: to contribute to sustainable development in developing countries, and to make it easier for countries with reduction commitments to achieve their targets. The CDM is supposed to orient the future development of the less industrialized countries down a more sustainable path, and to prepare developing countries to contribute to mitigation without undertaking binding commitments. The credits acquired under the CDM are called Certified Emissions Reductions (CERs).

While majority of the CDM projects are in the electricity sector, many smaller Certified Emission regulation (CER) projects are in the reduction of nitrous oxide (N_2O), trifluoromethane, (HFC-23) and methane (CH_4).

If resulting from afforestation and reforestation projects (the only two sink activities allowed), they are either temporary or long-term CERs. A levy of 2 percent of the number of CERs issued for every project is to go to an adaptation fund for vulnerable countries. Projects undertaken in the Least Developed Countries (LDCs), as well as small-scale projects, are exempt from this levy. Because the market offer is potentially unlimited, and developing countries have no reduction commitments, both seller and buyer have an incentive to inflate the emission reductions achieved. Therefore, to ensure transparency and accountability, the mechanism is subject to control by the CDM Executive Board,

which, in turn, responds to the governing body of the Kyoto Protocol, the Conference of the Parties serving as the Meeting of the Parties (COP/MOP).

To participate in the above mechanisms, Annex 1 parties must meet certain eligibility requirements. These include: ratifying the protocol; calculating their assigned amount; having a national system for estimating emissions and removals of greenhouse gases within their territory; putting in place a national registry to record and track the creation and movement of tradable units; and reporting annually on emissions and removals to the UNFCCC secretariat. The Facilitative Branch of the Compliance Committee oversees conformity with these requirements. Most of the rules and modalities that govern the mechanisms were established in a package of decisions known as the Marrakesh Accords, which resulted after many difficult political issues were agreed in Marrakesh (Morocco, NW Africa) in 2001. They were adopted, along with the Kyoto Protocol, at the first session of the COP/MOP 4 in Montreal in December 2005.

6.10. Carbon Permits

Carbon permits may be issued to companies through governmental agencies and allow companies to emit up to a specified level of CO_2. The total number of issued permits from governmental agencies equals the national limit on emissions. CO_2- generating companies may reduce emissions by using lower carbon coals or increasing the use of cleaner generating plants. Generators that reduce emissions will give permit to the other generator. Other generators who exceed the limit of the permit may purchase permits at the market price instead of reducing emissions if it is more cost effective. Thus, companies that can easily reduce emissions will do so, and those for which it is harder will buy credits that reduce greenhouse gases at the lowest possible cost to society. Emission permits can also be banked for future use.

6.11. The European Union Emission Trading Scheme (EUETS):

The EU Emissions Trading System (EU ETS) is the world's largest tradable carbon permits program. The program was initiated across the EU's 25 Member States covering about 45% of the EU's total CO_2 emissions and includes the electric power sector and other major industrial sectors. The first phase was from 2005 to 2007 and the second phase was between 2008 and 2012. During the first phase, Member States auctioned up to 5% of their allowances and in the second phase, up to 10% of allowances.

In the system, the aggregate cap on emissions is set by each EU government agency, and the total number of emission allowances is defined to provide the owner the right to emit units of emissions. The amount of emissions is capped, whereas the permit prices are uncertain. These permit prices are determined by economic conditions, generally, stronger economic growth means a higher permit price. Critics claim that the ETS has done more for power-generating companies, than it has curbed pollution. First, power generators emit a tremendous amount of pollution and monopolize the carbon market. Also, permit holders find they have unexpectedly valuable property rights because carbon permits are usually handed over freely, rather than auctioned. Second, there are no signals that the carbon permit is helpful in switching to cleaner fuel. That is not just because gas has been so much

more expensive than coal, but because the first phase of the ETS lasts only three years. Because investments to reduce emissions have payback periods of five or more years, investors are wary.

The ETS was originally designed to meet the targets set by the Kyoto Protocol. Its objective is to stabilize the greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. In the Kyoto Protocol, mechanisms such as International Emissions Trading (IET), Joint Implementation (JI) and the Clean Development Mechanism (CDM) provide options for members to fulfill their targets. IET provides the trading of assigned amount units (AAUs) between Annex I Parties in the Kyoto Protocol, JI enables Annex I parties to get credits for joining the projects that reduce emissions, CDM enables Annex I parties to get credit for projects resulting in emissions reductions in non‑Annex I parties.

In the United States, the example of a successful emission trading system to date is the SO_2 trading system under the framework of the Clean Air Act (CAA). Under this program, SO_2 emissions are expected to fall by 50 percent during 1980-2010. Compared to the proven success of the SO_2 trading program in the United States, carbon trading has some specific features that make it more complicated.

Carbon emissions are an international issue, rather than a domestic one. Complexities may arise in setting up baseline projections against which to monitor and verify net emissions reductions, particularly with regard to the CDM. Usually, large amounts of SO_2 come from coal-burning generation plants, making it relatively easy to monitor a plant's fuel use and emissions rather than to construct and maintain a trading system to ensure compliance. On the other hand, carbon emission come from many different sources, such as households, commercial and industrial facilities, transportation systems, and fossil fired generating plants. Therefore the development and operation of a monitoring and trading system for carbon emissions would be complicated.

6.12. 'Price cap' or 'safety valve' mechanism:

Although the approach of tradable permits can ensure that a certain quantity of emission will be reduced, it does not provide any certainty of price. So price uncertainty may be addressed by a 'price cap' or 'safety valve' mechanism, which guarantees that the government will sell additional permits if the market price of allowances hits a certain price. A safety valve mechanism does not provide any certainty that a particular emission level will be met, and it requires additional administrative complexity to link a domestic program with or without a safety valve program or with a different safety valve price. Several studies concluded that tradable permit program may be less appropriate for developing countries due to their lack of appropriate market or enforcement institutions.

There has been debate on the relative merits of carbon permits versus carbon taxes to achieve emission reductions. Carbon permit systems fix the overall carbon emission level, while prices vary. On the other hand, carbon taxes fix the price, while the emission level quantity is allowed to vary according to economic activity. Therefore, carbon permits and carbon taxes are called quantity and price instruments, respectively. There are major drawbacks for each system. Carbon permits create uncertainty about the cost of compliance for firms, because the price of a permit is unknown; carbon taxes cannot guarantee the amount of emissions reduction.

Recently, the ‘safety valve’ has been suggested as the third option as it is a hybrid of the price and quantity instruments. The system is similar to a carbon permit system, but the maximum permit price is limited. Permits can be either purchased from the carbon market, or government, at a specified price. This system is designed to overcome the fundamental disadvantages of both systems, while providing flexibility.

6.13. Additionality tool & Leakage:

As CDM projects are implemented in countries without emission targets, the ‘additionality tool’ became important to avoid generating fictitious emission reduction credits through ‘business as usual’ activities. Several tests of additionality are mentioned. These include investment additionality and environmental additionality. The CDM Executive Board has developed an ‘additionality tool’ that project proponents can use to test and demonstrate the additionality of a CDM project.

If a project is ‘additional’, the next step is to determine a ‘baseline’ – the emission status before the project had not started. In order to account for any emissions that occur outside the CDM project, a term known as ‘leakage’ is included.

According to the UNFCCC CDM, leakage is defined as the net change of anthropogenic emissions by sources of GHGs that occur outside the project boundary and which is measurable and attributable to the activity of the CDM project.

6.14. United States and Kyoto Protocol

The Kyoto Protocol has become a debate between North and South (United States & its alleys and the rest). It is interesting to note that although the United States was the leader in drafting the Montreal Protocol and to implement it, this is not the case with regard to the Kyoto Protocol. The reason for this is the payoff structure is different from that of the Montreal Protocol for the United States and its key allies.

For most of the key countries, unilateral compliance with the Montreal Protocol requirements was justified and boosted industry, in the sense that better technology needed to be developed to deal with changing things such as refrigerators, and American industry took the lead. On the other hand, the Kyoto Protocol might mean some cut-backs in emissions with an inverse impact on industries (but can boost industry if innovative greener technology is utilized).

The Stern Review (a United Kingdom government sponsored report on the economic impacts of climate change) concluded that one percent of global gross domestic product (GDP) is required to be invested to mitigate the effects of climate change, and that failure to do so could risk a recession worth up to 20 percent of the global GDP. Although some companies in the United States have begun working towards reducing greenhouse gas emissions, as a nation, the United States is still not part of the Kyoto Protocol. It is reasonable to predict that, when it comes to climate change, the United States will only move to ratify an international agreement reducing greenhouse gases if the perceived domestic costs of reduction decrease, or the benefits increase, or both. Without the United States participating, the success of any agreement will most likely be limited, because such a large amount of the world’s greenhouse gas emissions are coming from the United States.

7. Engineering aspects of mitigation of climate change

The consensus of scientific studies suggests that the planet has warmed due to human-caused greenhouse gas emissions. Moreover, scenarios of future warming give disappointment. For example, if human-caused emissions remain near their current rate of increase, atmospheric carbon dioxide is expected to exceed 500 parts per million sometime between 2050 and 2100, causing global temperatures to increase by at least 2°C (3.6°F) and more likely by about 5°C (9°F). Based on paleo-climate data, these values of atmospheric carbon dioxide and global temperature significantly exceed those of at least the past 420,000 years.

Many countries that attended the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto promised to learn how to mitigate the problem of climate change by managing the global carbon cycle. This resolution particularly shows the studies on engineering aspects of research on climate change issues and for alleviating the global warming problem.

Recently, there have been serious discussions about deliberately manipulating Earth's climate system to counteract human-caused global warming and its unwanted effects. These manipulations are called **global engineering on climate change**. Most global engineering proposals fall into two general types: (1) reducing the amount of sunlight reaching the Earth or (2) removing human-caused greenhouse gases from the atmosphere and disposing them of at somewhere else. Examples of the first type include spraying sulfate aerosols into the atmosphere to mimic the cooling effect of a major volcanic eruption or installing thousands of reflective sunshades in satellites in their orbits to block incoming sunlight. Examples of the second type include removing atmospheric carbon dioxide and placing it into subsurface layers within Earth or into the deep ocean.

How the oceans naturally counteract global warming, how the ocean system reduces greenhouse gases, and what potential solutions exist is discussed below.

7.1. THE OCEAN ACTS AS A BIOLOGICAL PUMP:

Because the oceans naturally absorb vast amounts of carbon dioxide from the atmosphere, the oceans therefore play a vital role in reducing the greenhouse effect. In fact, the vast majority of carbon dioxide in the ocean atmosphere system is found in the ocean because carbon dioxide is approximately 30 times more soluble in water than the other common gases. Currently, a little less than half of the carbon dioxide released by mankind remains in the atmosphere; about a third enters the oceans and the rest is absorbed by plants.

What happens to the carbon dioxide that enters the ocean? Most of it is incorporated into organisms through photosynthesis and through their secretion of carbonate shells. Moreover, carbon dioxide is cycled very effectively from the atmosphere to the ocean. In fact, more than 99% of the carbon dioxide added to the atmosphere in the geologic past by volcanic activity has been removed by the ocean by soaking it up and removing it from the environment as sea floor deposits as marine sediments like biogenous calcium carbonate and fossil fuels. Thus, the ocean acts as a *repository* (or *store house*) for carbon dioxide, This process of removing material from sunlit surface waters to the sea floor is called a **biological pump** because it pumps carbon dioxide and nutrients from the upper ocean waters and accumulates them in deep-sea waters and sea floor sediments (Figure 4).

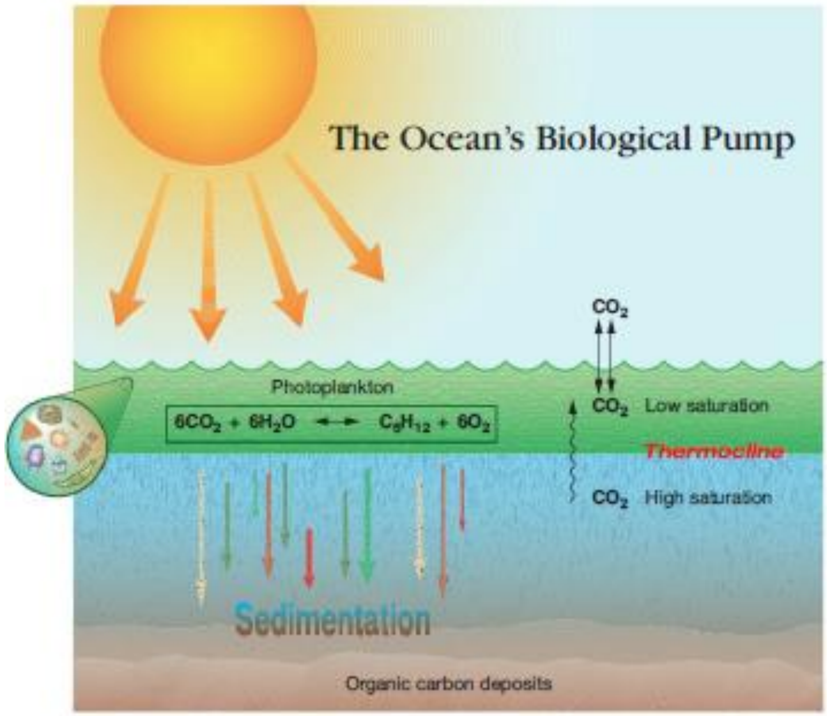

FIGURE 4 The Schematic view of the ocean's biological pump, which removes carbon dioxide from the atmosphere.

7.2. THE OCEAN ACTS AS A THERMAL SPONGE:

Due to its unique thermal properties, water can absorb large quantities of heat without much change in temperature. Thus, the thermal properties of the ocean make it ideal for minimizing the increase in global temperature. Further, the oceans serve as the earth's biggest single reservoir for surplus energy. If this were not the case for the oceans, the planet would have experienced much more greater increase in temperature. In essence, the oceans act as a thermal sponge, absorbing heat and minimize the amount of warming experienced. Interestingly, the recent studies indicate that the heat content of the oceans also has been increasing (Figure 5).

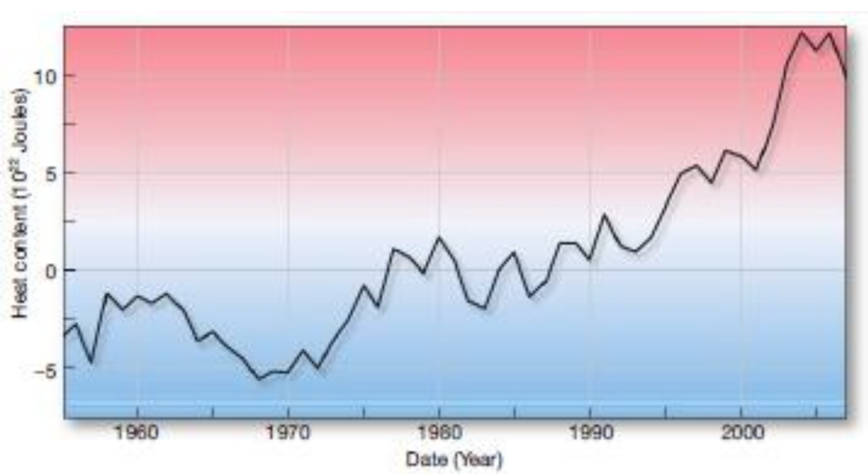

FIGURE 5. Graph showing how the heat content of the oceans has increased since the 1950s.The short-term kinks of the curve shows the influence of anthropogenic factors and El Niño/La Niña events on natural variation of the ocean's heat content.

7.3. Other Possibilities for Reducing Greenhouse Gases

There is much debate about what to do about the increasing human-caused emissions in the atmosphere. One idea is to eliminate human emissions before they even get into the atmosphere. Other proposals involve using the oceans to reduce the amount of human-caused emissions in the atmosphere. Let s examine two of these proposals.

7.3.1. THE IRON HYPOTHESIS

Stimulating productivity in the ocean has been proved successful for removing excess carbon dioxide from the atmosphere. Through photosynthesis, phytoplankton such as diatoms convert carbon dioxide dissolved in the ocean to carbohydrate and oxygen. By capturing and removing additional amounts of carbon dioxide in the ocean using man's technology, the ocean's ability to absorb more heat-trapping carbon dioxide from the atmosphere will increase. Thus cools the planet.

Areas of the ocean that have relatively low productivity, such as the tropics, are a good place to stimulate productivity which helps in enhancing the removal of carbon dioxide from the atmosphere. In 1987, oceanographer John Martin recognized the reason for the low productivity of tropical oceans as the absence of the essential nutrient iron. So he proposed the fertilization of the ocean with iron to increase its productivity. In 1993, Martin s associates tested the idea by adding a soluble solution of finely ground iron to a small patch of ocean near the Galápagos Islands in the Pacific Ocean. Their results, combined with the results of about a dozen other open-ocean experiments worldwide since 1993, confirmed that adding iron to the ocean increased phytoplankton productivity up to 30 times. In fact, some of the patches of iron-enriched high productivity were visible to Earth-orbiting satellites. Subsequently afterwards, this idea became known as the **iron hypothesis** (Figure 6).

It may be interesting to note in this regard that a large open-ocean experiments have been proposed and several private companies have also filed patents for ocean-fertilization technologies to make the ocean fertilization on a commercial scale.

Draw backs of the Iron hypothesis:

Although the results of these small-scale open-ocean experiments proved successful, it has other long term disastrous effects. A more serious problem, however, is the long-term global environmental effects of increasing the amount of carbon dioxide and oxygen in the ocean by stimulating biological productivity. For example, there is concern that severe oxygen depletion of seawater could occur in areas where iron fertilization is conducted because of the large population of algae that is produced eventually dies and decomposes by consuming dissolved oxygen.

In addition, this decomposition releases byproducts such as carbon dioxide and nitrous oxide both are important greenhouse gases. It is well known that higher amounts of carbon dioxide in the ocean lead to increased ocean acidity (PH), which is a problem for marine life and marine ecosystems. Another problem is from the interference with the natural ecology of large oceanic regions and its unforeseeable consequences.

Some of the concerns about any type of global engineering include the justification for intentionally altering any of Earth's systems on a global scale, the possibility of harmful side effects, who should pay for its implementation, and whether it would have to be constantly maintained. In addition, skeptics of global engineering point out that it distracts from perhaps the most immediate way of limiting human-caused climate change: reducing the amount of greenhouse gases that are spewed into the atmosphere.

So further investigation to overcome these draw backs is necessary and so these experiments did not gain importance at present.

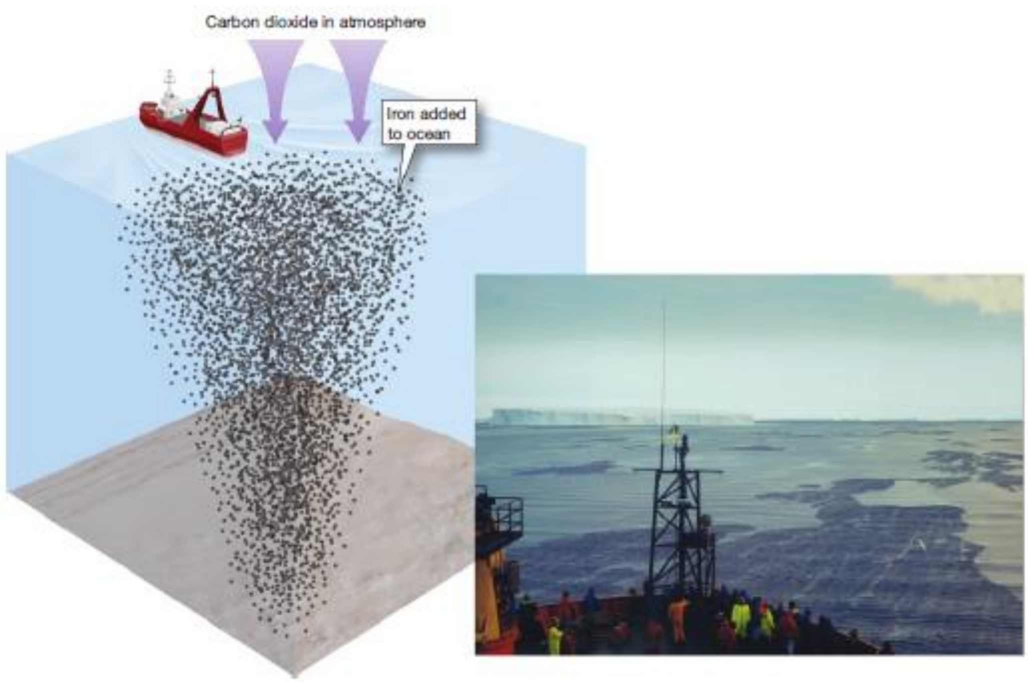

FIGURE 6. The iron hypothesis. Seeding the ocean with the essential nutrient iron stimulates productivity and draws the heat-trapping carbon dioxide from the atmosphere which will be used by phytoplankton. Some of this carbon dioxide tied up as tissue or in fecal pellets, sinks toward the sea floor, thereby removing it from the environment. Photo (*inset*) shows a view from a research vessel involved in applying finely-ground iron to the ocean near Antarctica.

7.3.2. SEQUESTERING EXCESS CARBON DIOXIDE INTO THE OCEANS:

The kind of reduction of CO_2 by collecting CO_2 at point sources (such as power plants) and either storing or converting in to other forms by any other methods is known as carbon capture and storage (CCS). If CCS is applied to modern conventional power plants, CO_2 emission into the atmosphere could be reduced by 80-90 percent. Injecting CO_2 into ocean depths greater than (1,000 m) or into deep geologic formations is called carbon sequestration.

Successful experiments have involved capturing emissions of the factories either before they are released into the atmosphere or directly from the atmosphere and then pumping the gas into the deep ocean or underground reservoirs is shown in Fig 7. This removes carbon dioxide from the atmosphere and thus reduces global warming. If the deep ocean is used as a disposal site for carbon dioxide, however, there are concerns about how it would impact deep-sea chemistry and, marine ecosystems. In addition, it is unclear how long the sequestered carbon dioxide will stay at the place of sequestration in the deep ocean due to sluggish deep-water circulation patterns. However, the capture of carbon dioxide emissions and their subsequent disposal into deep reservoirs beneath the sea floor is already occurring at a handful of test sites worldwide and gaining popular due to easy and cheap technology.

No-till farming, residue mulching, cover-cropping, and crop rotation are some of the other methods that are employed to sequester carbon into soil. Using pyrolysis technique, half of the carbon in biomass can be reduced to charcoal and, thus, decrease the potential to act as a carbon source. The charcoal is later deposited in soil.

Carbon sequestration can also be accomplished by maintaining or enhancing natural processes such as managing forest ecosystems, enhancing net oceanic carbon uptakes and sequencing the genomes of micro-organisms for carbon management.

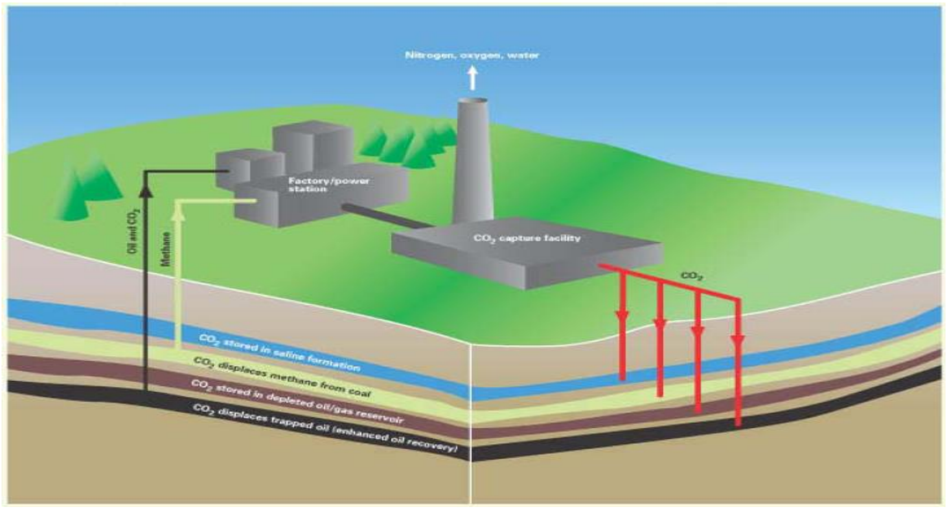

Fig.7. Method of carbon sequestration into the soil and ocean from the exhausts of the factories

7.3.3. Exo thermal reaction technique:

CO_2 is exothermically reacted with abundantly available metal (Mg and Ca) oxides, which produce stable carbonates. The Engineering technology used for CO_2 capture in this process is shown in Fig.8. Presently, there are three techniques in use: post-combustion, pre-combustion, and oxy-fuel combustion. In post-combustion processes, CO_2 is captured from flue gases (the gas that exits to the atmosphere through a pipe) at power stations. The pre-combustion technique is widely applied in fertilizer, chemical, gaseous fuel (hydrogen and methane), and power production. In these cases, the fossil fuel is gasified and the resulting CO_2 is easily captured from a relatively pure exhaust stream. In the third type (oxy-fuel combustion) the lignite is burned in oxygen instead of air and produces a flue gas consisting only of CO_2 and water vapor. This is cooled and condensed to a pure CO_2 stream that can be transported to the sequestration site and stored.

To decrease the amount of carbon emitted into the atmosphere under CCS, governments are using command and control regulations.

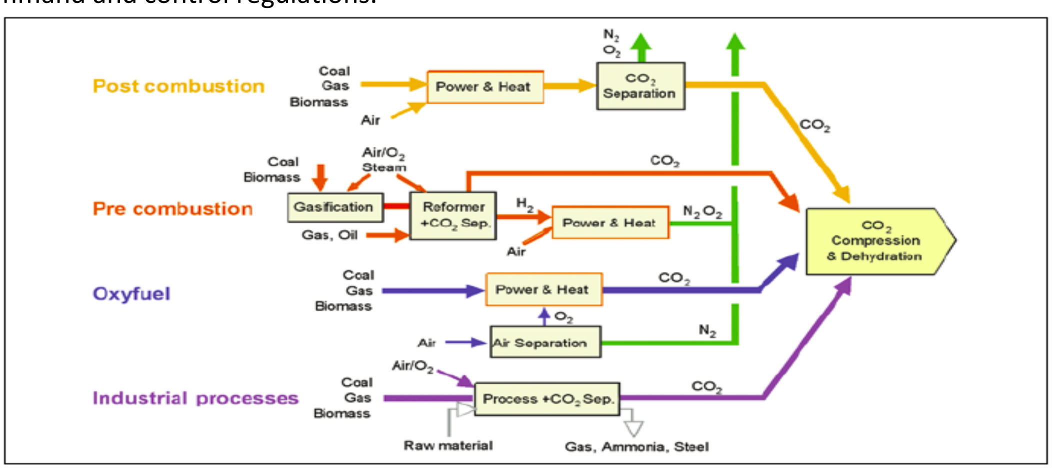

Fig.8. The Engineering: technology for CO_2 capture

8. Inter-governmental Panel on Climate Change (IPCC)

The world's primary body for crafting a response is the Intergovernmental Panel on Climate Change (IPCC), a UN-sponsored activity that holds periodic meetings between national delegations on the problems of global warming, and issues notifications, working papers and assessments on the current status of the science of climate change, impacts, and mitigation.

The first World Climate Conference organized by the World Meteorological Organization (WMO) expressed concern about significant regional and global changes of climate due to human's activities on Earth. The conference appealed to nations of the world to foresee and prevent potential human-made changes in climate that might have adverse effects on human race. A joint UNEP/WMO/ ICSU conference convened in Villach, Austria on the “Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts.” The conference concluded that a rise of global mean temperature could occur due to the increasing greenhouse gases and warming of the globe could result in sea level rises. This warming and probable rate and degree of warming are closely linked with other major environmental issues which could be profoundly affected by policies on emissions of greenhouse gases, just like the emissions of chloro fluoro- compounds under the Montreal Protocol and their effect on ozone depletion.

Recognizing the problem of potential global climate change, the WMO and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in November 1988 and was open to all members of the United Nations and WMO, with the aim of assessing in a comprehensive, objective, open, and transparent manner the scientific, technical, and socioeconomic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts, and options for adaptation and mitigation. Although the WMO and UNEP were the two main organizations involved in the creation of the IPCC, there were other intergovernmental organizations as well as nongovernmental organizations that were involved in establishing the IPCC. Also, the UN General Assembly, recognizing the need for international cooperation on climate change, joined the call through its resolution on “Protection of the Global Climate for Present and Future Generations of Mankind” during their 43rd session, held in 1988. The IPCC does not carry out any research on its own, nor does it monitor climate-related data or other relevant parameters. On the contrary, IPCC bases its assessment mainly on peer reviewed and published scientific/ technical literature.

As an intergovernmental body jointly established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), the IPCC has successfully provided policymakers with the most authoritative and objective scientific and technical assessments, which are clearly policy relevant.

A small bureau of 15 was created to oversee the work of the panel and three working groups were also formed: Working Group I address topics including greenhouse gases and aerosols, processes and modeling, observed climate variations, and change. The experts of Working Group I have concluded that emissions from human activities are substantially increasing the atmospheric concentration of greenhouse gases and this will result in warming of the Earth's surface.

Working Group II assesses the climate change impact on agriculture and forestry, natural terrestrial ecosystems, hydrology and water resources, human settlements, oceans and coastal zones, and seasonal snow cover, ice, and permafrost.

Working Group III has further established subgroups to define mitigative and adaptive response options in energy, industry, agriculture, forestry, and other human activities, including coastal zone management. Each working group has two co-chairs, one from a developed country and another from a developing country, and a technical support unit.

IPCC activities, including travel costs for experts from developing countries and countries with economies in transition, are financed through voluntary contributions from governments.

The IPCC has an official definition for climate change: climate change refers to a statistically significant variation in either the mean state of the climate, or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forces, or due to persistent anthropogenic changes leading to change in the composition of the atmosphere or in land use.

8.1. IPCC Reports:

The IPCC, in its two and half decades of existence, has produced many reports; four assessment reports have been produced at the behest of the UN General Assembly. Beginning in 1990, this series of IPCC Assessment Reports, Special Reports, Technical Papers, Methodology Reports and other products have become standard works of reference.

The *First IPCC Assessment Report (FAR)* completed in 1990 provided the impetus for the formation of the UN Framework Convention on Climate Change (UNFCCC) by the UN General Assembly through Intergovernmental Negotiating Committee (INC). The UNFCCC is an international treaty joined by most countries and was created in 1994. The UNFCCC provided the overall policy framework for addressing climate change and for coping with the impacts from inevitable temperature increases.

The *Second IPCC Assessment Report (SAR), 1995* prepared a comprehensive report on climate change and was recognized as the most authoritative assessment of climate change, its impacts, and response options. It indicated that the continued rise of greenhouse gases in the environment would have serious socioeconomic and environmental impacts, especially for developing countries. This second IPCC report, provided input to the negotiations of the Kyoto Protocol.

The *Third IPCC Assessment Report (TAR), 2001* also known as TAR, set out to meet new requirements. Some of the facts according to IPCC, Executive summary, January 2001 are: warming during the past 50 years can be attributed to humans; global surface temperature is expected to increase by 1.4–5.8^{0} C by 2100, and warming on this scale has not occurred during the previous 10,000 years.

The *Fourth IPCC Assessment Report 2007(ar4)* was prepared with an aim to emphasize new findings, therefore, the structure and mandates of the Working Groups were kept unchanged. The report was presented to the United Nations General Assembly in 2007. Some of the observed impacts are: 11 of the previous 12 years ranked among the 12 hottest on record since 1850, Global sea-level rise

had accelerated, mountain glaciers and snow cover have declined, and more intense and longer droughts have been observed over wider areas since the 1970s. The report also established direct links to human health and other issues and has raised international concern over climate change and need to act quickly to prevent the catastrophic impacts of climate change. The IPCC shared the 2007 Noble Peace Prize with Al Gore for its efforts in bringing climate change to the forefront.

The *Fifth IPCC Assessment Report (AR5)* came out in 2014.The Mitigation of Climate Change is the third part (WGIII) of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The volume provides a comprehensive and transparent assessment of relevant options for mitigating climate change through limiting or preventing greenhouse gas (GHG) emissions, as well as activities that reduce their concentrations in the atmosphere.

A description of mitigation options for the various societal sectors that contribute to emissions forms the core of the working Group III report that deals on mitigation. Seven chapters cover mitigation options in energy supply, transport, buildings, industry, agriculture, forestry and waste management, with one additional chapter dealing with the cross-sectoral issues. The report has provided the reader with an up-to-date overview of the characteristics of the various sectors, the mitigation measures that could be employed, the costs and specific barriers, and the policy implementation issues. In addition, estimates are given on the overall mitigation potential and costs per sector, and for the world as a whole. The report combines information from bottom-up technological studies with results of top-down modelling exercises. Mitigation measures for the short term are placed in the long-term perspective of realizing stabilization of global average temperatures. This provides policy-relevant information on the relation between the stringency of stabilization targets and the timing and amount of mitigation necessary. Policies and measures to achieve mitigation action, both at national and international levels, are also covered. The link between climate change mitigation, adaptation and sustainable development has been further elaborated in the relevant chapters of the report, with one chapter presenting an overview of the connections between sustainable development and climate change mitigation.

This report highlights that despite the growing number of mitigation policies, GHG emission growth has accelerated over the last decade. The evidence from hundreds of new mitigation scenarios suggests that stabilizing temperature increase within the 21st century requires lot of sacrifice and deviation from business-as-usual (normal present life). To deviate from present day normal life, it has shown variety of emission pathways for limiting the temperature increase to below 2 °C relative to pre-industrial level. But this goal is associated with considerable technological, economic and institutional challenges. A delay in mitigation efforts or the limited availability of low carbon technologies further increases these challenges. So all countries should concentrate in these lines to mitigate the increase of temperature.

9. International Policy

International policy is complex because of the necessity to consider the needs of each sovereign nation against economies, global environmental impact, and contributions to human-induced climate change. Much of the work toward international cooperation is done through the United Nations, an international organization with nearly all countries as members.

The United Nations facilitates discussion and commitment, though it has limited authority or power. Members agree that something must be done about climate change and the environment; however, getting member nations to agree on solutions is harder. Conflicts and disagreements usually include protection of national interests by not turning authority over to the United Nations, wording of agreements that appears not to protect the interest of private industry or national interest, and economic differences between developing and developed countries.

9.1. Historical back ground of International Policy

The UN Environment Programme (UNEP) was formed in 1972 with the specific purpose of encouraging collaboration on conservation and development. In 1977, the international community adopted a Plan of Action to Combat Desertification due to impacts on economy, society, and environment. In 1991, the UNEP concluded that even with some successes, land degradation due to desertification had increased, and at a 1992 conference proposed sustainable development and the UN General Assembly established an Intergovernmental Negotiating Committee on Desertification (INCD) to prepare a Convention to Combat Desertification, which was adopted in 1994, and came into force on December 26, 1996. Over 179 countries were parties to the convention as on March 2002.

The Montreal Protocol on Substances that Deplete the Ozone Layer was agreed on September 16, 1987, and entered into force on January 1, 1989, and has been ratified by 191 countries. At the 1992 UN Conference on Environment and Development, member nations agreed to work together to formulate solutions. The Convention on Biological Diversity (CBD) was adopted at the conference for commitments to maintain ecology balanced with economic development, though the United States disagreed with some document wording as not protecting biotechnology firms.

Developed countries committed under the initial negotiations are to take the majority of responsibility for creating policy and actions to mitigate climate change and reduce their output of emissions of greenhouse gases to 1990 levels by the year 2000. In debating further commitments, the participants discussed a variety of options, including policies and measures, as well as quantified emission targets.

The 1995 Berlin Mandate, under negotiation, requested more significant quantification of emissions and stricter policy to enforce reduction objectives in a certain period of time. The various participants presented and supported policy approaches with regard to the standards and taxation. Some proposals blended mandatory strict policy standards and taxation, along with a variety of options for reaching those goals.

Proposals from the European Union, the primary proponent of common and coordinated policy, listed specific actions including mandatory commitments, highly recommended commitments, and voluntary commitments. The United States and other participants favored target-based approaches to allow countries complete autonomy in choosing policies and measures.

By the late 1990s, working in voluntary partnerships was leading to reductions in conflict among stakeholders, new ideas on sustainable economic development and poverty alleviation, new thinking

about the relationship between conservation areas and the communities in and around them, and more focused application of existing resources. Finally, an addition to the UNFCCC treaty is the Kyoto Protocol, drafted in 1997 by 160 nations, calling for the 38 industrialized countries releasing the most greenhouse gases to cut their emissions to levels five percent of 1990 levels by 2012 to achieve a worldwide reduction of greenhouse gases.

The Kyoto Protocol could not gain support of the developed world, as the emission reduction levels were fixed to industrialized nations and emission standards require from developing countries some incentive-based policies. In the light of this experience, researchers made a variety of proposals, including the trading of carbon/emission credits as long as emissions can be quantified, control of conventional air pollutants, or improvement of agricultural productivity. Taking measures for limiting the extent of global warming from the greenhouse effect includes preventive measures (reducing emissions, enhancing carbon sequestration) and adaptive measures (construction to protect against the effects of climate change, improving water resources, and improving cultivation practices, or shifting crops to match the plants to ideal weather conditions for maximum production).

9.2. Future status of International Policy

While some international policies, like the Montreal Protocol on Substances that Deplete the Ozone Layer and the Convention to Combat Desertification retain support on a long term basis, an important policy that takes steps in controling greenhouse gas emissions (GHGs) like Kyoto Protocol did not get support by developed world. In the meanwhile, the measures for the reduction of GHGs agreed in the Kyoto Protocol ended by 2012.

So in determining future policy, the success of the target-based approach to reduce greenhouse gas emissions and its feasibility of enforcement may be critically examined.

The commitment is based on outcome, and coupled with emissions trading, provides economic benefits as well as freedom to apply reduction strategies in the most cost-effective manner. This works for industrialized nations, with already established economies. Developing countries may not accept imposed limits on emissions, because those limits may hamper their potential growth. As developing countries have multiple concerns on environmental issues like water quality, air quality, poverty, and health issues like access to sanitation, nutritious food, and health services to improve first, they may not show interest in global issues.

So continuous negotiations and commitments are needed to continue on the international cooperation on climate change mtigation policy. As discussed at the Climate Dialogue at Pocantico, the best policy could be giving a flexibility of adapting a policy that is suitable to a country rather than imposing stringent restrictions which are not practicable uniformly. This seems to be the most important factor in gaining support by allowing countries to develop national policies in developing countries to reduce emissions on a more individual basis, instead of being limited to strict limits set by an economy-wide emission limit. Within this framework, countries may need to establish quantifiable measurements of emission impacts.

Also to be considered is the previously unused policy options like carbon taxes on all fossil fuels, like gas, oil, coal, and the electricity generated from these sources. These taxes would shift the burden of emission reduction to the consumer by inflating the price of using carbon-based energy and making the use of energy conservation measures and alternative resources more attractive and cost-effective, as well as increasing the demand for alternative sources.

The trading of carbon credits (to a nation allocated a certain permissible level of carbon emissions and the ability to sell leftover allocations to nations who have exceeded their allocation limits), subsidizing non-carbon-based fuel providers instead of fossil fuel providers, and research and development expenditures promoting the commercialization of alternative technologies and promoting the transfer of technology to developing nations could also help.

Any measures taken to prevent global climate change will have economic effects, both positive and negative, on the economy, including production, employment, and investment. Continued scientific research on climate and atmosphere, as well as environmental education and continued voluntary dialogue between countries on the future of global environment and economic policies, can help lead to action and global policy development to overcome the limitations of determining economic policies.

Any Policy that is made must take into account the damages caused by the impacts of climate change.

All the potential impacts of climate change will have an impact on the economy, and policy, international, national, or local, must take these possibilities into account.

The emissions crediting through the Clean Development Mechanism of the Kyoto Protocol already generated 870 million tons of emission credits with the current estimated value of $6 to $9 billion. This monetary value makes carbon crediting a viable source of income, especially for developing countries and those with carbon sequestration in forests and agricultural areas. This type of market enterprise would require independent verification.

The limitation of this program might be creating disincentives for industrialized nations to reduce emissions with the option to purchase carbon credits or not to agree to the program at all if they do not get benefit from the income produced.

The quantification of standards thus so far has been based on present levels and emissions assessments. For the developing countries, the strategy should be not on reduction of emissions, but should be on limiting the emissions by developing the renewable energy and improved social structures.

As environmental awareness increases and more individuals choose to adapt to climate-preserving strategies, it will have a positive cumulative effect on reduction emissions.

Improved agricultural practices remove carbon from the air. In some cases, the effectiveness of the emissions reduction policy will be difficult to determine. The most vital part of international policy is raising awareness of the environment and what can be done to combat climate change and the effects of climate change.